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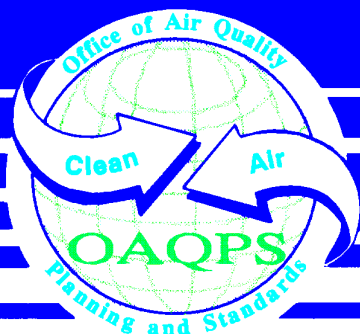
Office Of Air Quality
Planning And Standards
Research Triangle Park, NC 27711

EPA-452/R-01-017
December 2001
FINAL REPORT

Air

Economic Impact Analysis of the Refractory Product Manufacturing NESHAP

Final Report



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Economic Impact Analysis of the Refractory Product Manufacturing NESHAP

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**U.S. Environmental Protection Agency
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Document Number: EPA-452/R-01-017**

**Final Report
December 2001**

Disclaimer

This report is issued by the Air Quality Standards & Strategies Division of the Office of Air Quality Planning and Standards of the U.S. Environmental Protection Agency (EPA). It presents technical data on the economic impacts of the National Emission Standard for Hazardous Air Pollutants (NESHAP), which is of interest to a limited number of readers. It should be read in conjunction with other background information and reports prepared in support of the Refractory Product Manufacturing NESHAP. Copies of this report and other material supporting the rule are in Docket A-2000-50 at the U.S. EPA Air and Radiation Docket and Information Center located at 401 M St. S.W. Washington, D.C. 20460 (room number M1500). You may also contact the docket office by phone at (202)260-7549, by fax at (202)260-4400, or by e-mail at A-and-R-Docket@epamail.epa.gov. The EPA may charge a reasonable fee for copying. Copies are also available through the National Technical Information Services, 5285 Port Royal Road, Springfield, VA 22161. Federal employees, current contractors and grantees, and nonprofit organizations may obtain copies from the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711; phone (919) 541-2777.

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LIST OF ACRONYMS

NESHAP - National Emission Standard for Hazardous Air Pollutants
CIP - Cold Isostatic Press
NAICS - North American Industrial Classification System
SBREFA - Small Business Regulatory Enforcement and Fairness Act
OAQPS - Office of Air Quality Planning and Standards
HAPs - Hazardous Air Pollutants
HCl - Hydrochloric Acid
HF - Hydrogen Fluoride
POM - Polycyclic Organic Matter
CR4 - Four-firm Concentration Ratio
CR8 - Eight-firm Concentration Ratio
HHI - Herfindahl-Hirschmann index
MACT - Maximum Achievable Control Technology
RCF - Refractory ceramic fibers
RFA - Regulatory Flexibility Act

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards (OAQPS) is developing National Emission Standards for Hazardous Air Pollutants (NESHAP) under Section 112 of the 1990 Clean Air Act for the refractory manufacturing industry.

This economic impact analysis (EIA) of the proposed NESHAP for the refractory products manufacturing industry provides information about the estimated costs and economic impacts of the proposed NESHAP. This section presents a summary of the costs of complying with the proposed NESHAP and the estimated economic impacts resulting from these costs.

ES.1 Costs of Compliance

Out of 167 facilities producing refractory products, the Agency has identified eight refractory manufacturing facilities as possible major sources of HAPs. Of these eight, five are projected to incur emissions control costs to comply with the NESHAP and the other three are projected to incur only recordkeeping costs. Four facilities are estimated to incur costs to install emissions control capital equipment. Based on the model, EPA expects the fifth facility will close its operation because the costs of control will exceed revenue. These capital costs of control technology range from \$383,000 to \$1.3 million and total \$3.5 million. The total annualized costs of the proposed NESHAP are \$1.61 million, including \$497,000 in annualized capital costs; \$718,000 in annual operating and maintenance costs for emissions controls; and \$166,100 in monitoring, recordkeeping, and reporting costs. Among the facilities incurring costs, the total annualized costs range from \$101,800 to \$649,000 and average \$201,000 per facility.

ES.2 Estimated Economic Impacts of the Proposed Refractories NESHAP

EPA used a simulation model of the market for refractory products to estimate impacts of the proposed NESHAP, including changes in market prices and quantities for refractory products; changes in costs, revenues, profits, and output for refractory manufacturers; and impacts on companies owning refractory manufacturing facilities, including impacts on small businesses.

EPA estimates that the price for refractory products will increase by less than 1 percent, and the quantity of refractory products sold will decrease by less than 0.1 percent. One refractory manufacturing facility is projected to become unprofitable and shut down under the proposed rule unless it chooses to become a nonmajor sources by altering its production processes. Overall, five facilities incurring emissions control compliance costs are projected to become less profitable and reduce their output, while 157 facilities not incurring costs or incurring only recordkeeping costs, are projected to become more profitable and increase their output as a result of the proposed rule. As a result, the net effect of the rule is to increase the industry's profit. Despite a single facility closure, output and employment are projected to decline only slightly as a result of the rule, because the facilities that do not incur compliance costs are projected to respond to the increased prices for refractory products by increasing their output and employment. EPA estimates the social cost of the proposed rule (computed as described in Appendix B) to be \$1.35 million, including a loss in consumer surplus of \$1.99 million and a gain in producer surplus of \$0.64 million.

For its analysis, EPA defined small businesses as those with 750 employees or fewer. EPA estimates that 59 of the 80 companies owning refractory manufacturing facilities may be small businesses. Only one of the facilities incurring compliance costs is owned by a small business, audits costs are only 0.37 percent of its baseline sales. Thus, the Agency does not project any significant adverse economic impacts for small businesses as a result of the proposed rule.

SECTION 1

INTRODUCTION

1.1 Introduction

A refractory is a material that retains its shape and chemical identity when subjected to high temperatures and is used in applications that require extreme resistance to heat. Specifically, refractories must be able to withstand temperatures above 538°C (1,000°F). Refractories are mechanically strong and heat resistant to withstand rapid temperature change and corrosion and erosion by molten metal, glass, slag, and hot gas. Refractories are used in kilns, furnaces, boilers, incinerators, and other applications.

Section 112 of the Clean Air Act lists 189 hazardous air pollutants (HAPs) and requires EPA to develop a list of categories of industries that emit HAPs. Section 112 then states that every major source of HAPs emissions will be required to reduce emission to levels that are equivalent to the average of the top 12 percent of the best performance. The Act defines major sources as those facilities that emit or have the potential to emit at least 10 tons per year of any single HAP or at least 25 tons per year of any combination of HAPs.

Refractory products manufacturing facilities have been identified as sources of several HAPs. The specific types and quantities of HAPs emitted from any particular facility are largely a function of the types of raw materials used and how those materials are processed. Many processes are used to produce refractory products. These processes can emit phenol, formaldehyde, methanol, and ethylene glycol, depending on the type of resin used. When used as binders or additives in the production of nonresin-bonded refractory shapes, ethylene glycol and methanol also are emitted from shape dryers and kilns. Pitch-bonded refractory heated pitch storage tanks, shape dryers, and kilns emit polycyclic organic matter (POM). The heated pitch storage tanks, shape preheaters, defumers, and coking ovens used to produce pitch-impregnated refractories also emit POM. Nearly all process units that are used to produce chromium refractory products emit chromium, and a small percentage of the chromium emitted from kilns that are used to fire chromium refractories is in the hexavalent form of chromium (Cr⁺⁶). Hydrogen fluoride (HF)

and hydrochloric acid (HCl) are emitted from kilns that are used to fire clay refractory products. Exposure to these substances has been demonstrated to cause adverse health effects such as irritation of lung, skin, and mucous membranes; effects on the central nervous system; and damage to the liver, kidneys, and skeleton. Formaldehyde and POM have also been listed as probable human carcinogens. EPA estimates that, of 167 refractory manufacturing facilities currently in operation, eight facilities may be major sources of HAPs. The Agency estimates that five of the eight major sources of HAPs will incur incremental costs to comply with the proposed NESHAP.

Emissions are treated as a free good but have a cost to society. These externalities include emission effects on humans and ecosystems. The major sources of HAPs in the refractory products industry that incur costs to reduce emissions will face economic consequences. The economic impacts to these five facilities will also affect the prices and quantities of refractories in the industry's market. This report evaluates the economic impacts associated with the NESHAP and reports estimated changes in price, production, profitability of facilities, and impacts to sensitive subsectors of the market, such as small businesses, foreign trade, and tribal communities.

1.2 Organization of this Report

This EIA report is organized as follows. Section 2 provides a detailed description of the production process for refractories, with discussion of individual refractory products, inputs, costs of production, demand, industry organization, and market structure for the refractories industry. Section 3 describes the estimated costs of complying with the proposed NESHAP. Section 4 discusses the economic impact analysis methodology and presents the results of the analysis. Section 5 presents the results of analyses to assess the impacts of the proposed NESHAP on small businesses.

SECTION 2

INDUSTRY PROFILE

In this section, we provide a summary profile of the refractory products industry in the United States, including the technical and economic aspects of the industry that must be addressed in the economic impact analysis. Section 2.1 provides an overview of the production processes and the resulting types of refractory products. Section 2.2 summarizes the organization of the U.S. coke industry, including a description of U.S. manufacturing plants, the companies that own these plants, and the markets for refractory products. Finally, Section 2.3 presents historical data on the refractory product industry, including U.S. production and consumption and foreign trade.

2.1 The Supply Side

Estimating the economic impacts associated with the options to regulate the refractory manufacturing industry requires characterizing the industry. This section describes the production process and inputs to and outputs of this process. In addition, characterizing the supply side of the industry involves describing various types of refractory products, by-products, and input substitution possibilities. This section describes costs of production and economies of scale.

2.1.1 Production Process, Inputs, and Outputs

The manufacturing process for refractories depends on the particular combination of chemical compounds and minerals used to produce a specified level of thermal stability, corrosion resistance, thermal expansion, and other qualities. Refractory manufacturing involves four processes: raw material processing, forming, firing, and final processing. Figure 2-1a illustrates the basic refractory manufacturing process, and Figure 2-1b depicts specific production processes for various refractory products. The production of refractories begins with processing raw material. Raw material processing involves crushing and grinding raw materials, classifying by size, calcining, and drying. The processed raw materials may then be dry-mixed with other minerals and chemical compounds, packaged, and shipped as product.

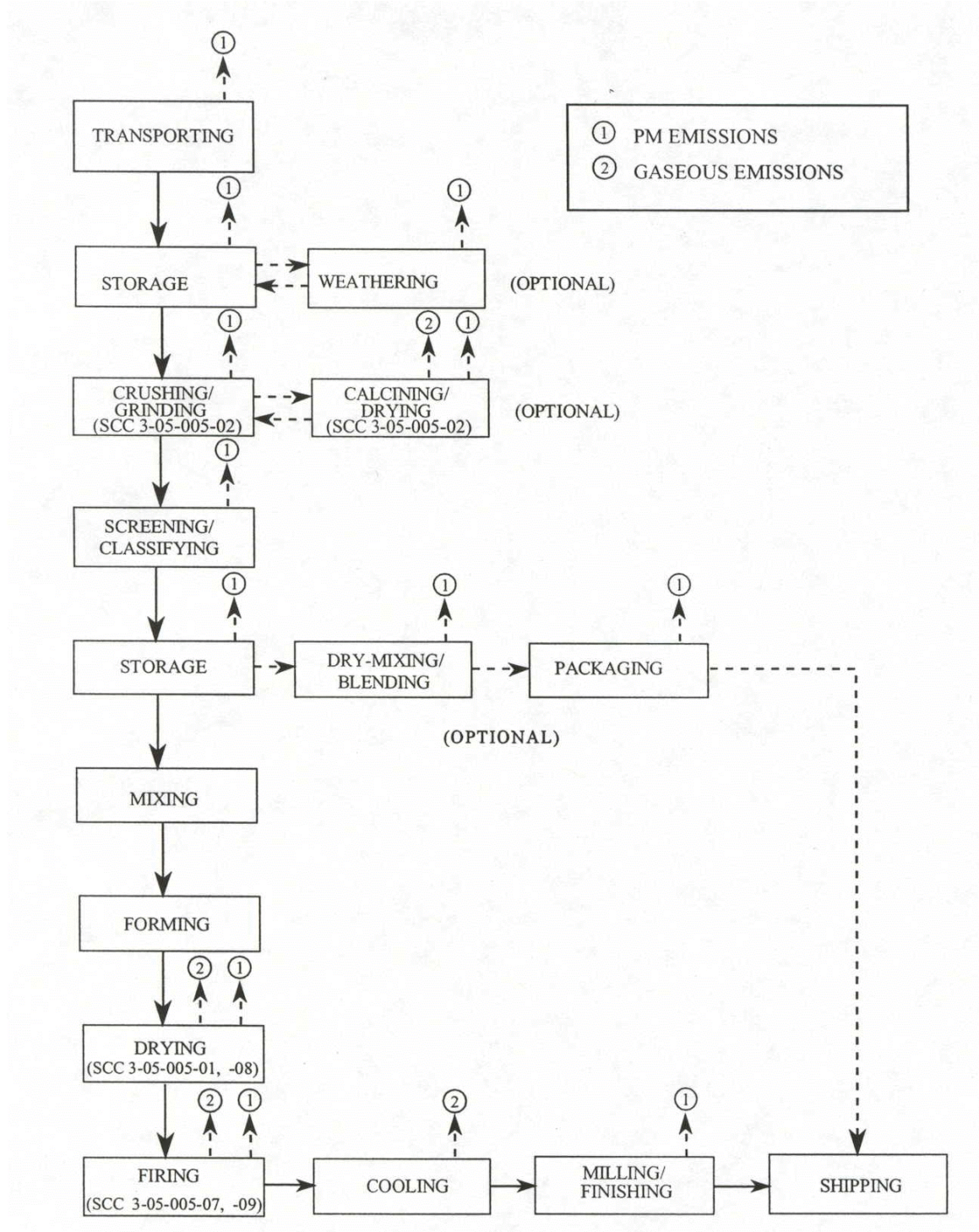


Figure 2-1a. Refractory Manufacturing Process Flow Diagram

Following the mixing process, the raw materials are formed into desired shapes. Liquids are added to the dry raw materials to facilitate adhesion in the pressing/forming phase. After the refractory is formed, the material is fired. Firing involves heating the refractory material to high temperatures in a periodic batch or continuous tunnel kiln to form a ceramic bond. This process gives the raw materials their refractory properties. The final processing stage includes milling, grinding, and sandblasting the finished product. For some products, final processing may also include impregnation with tar and pitch and product packaging (EPA, 1994 and The Technical Association of Refractories, Japan, 1998).

2.1.1.1 Machines Used in the Production Process

Several types of machines are used to produce refractories: mixing/kneading machines, presses, and kilns.

Mixing/Kneading Machines. Figure 2-2 illustrates different machines used to mix or knead refractory products. There are two types of mixing and kneading machines: fixed vessel and driven vessel. Mixing homogenizes more than two types of bulk materials, and kneading machines make a uniform coating layer. Mixing and kneading machines are equipped with mixing blades or muller wheels. Heating, cooling, or de-airing equipment may also be applied to the vessel. Mixing and kneading machines are used for manufacturing shaped and unshaped refractories. Unshaped refractories, however, are not processed any further (The Technical Association of Refractories, Japan, 1998).

Presses. Refractory pressing machines are broadly categorized into three groups: impact and static, vibrating, and cold isostatic press. Choosing between the three groups of presses largely depends on the type of raw materials used.

- **Impact and Static Presses:** Figure 2-3 illustrates a friction and a hydraulic screw press, two types of impact presses. Figure 2-4 is a diagram of a hydraulic screw press, a type of static press. Impact and static presses are typically equipped with a vacuum deaerator. Impact presses have a higher allowable maximum compacting force than static presses. However, static presses are finding increasing application in the production of sophisticated refractories such as submerged nozzles and shrouds and in the production of industrial ceramics. Bricks formed with static presses are flat, uniform, and compact (The Technical Association of Refractories, Japan, 1998).

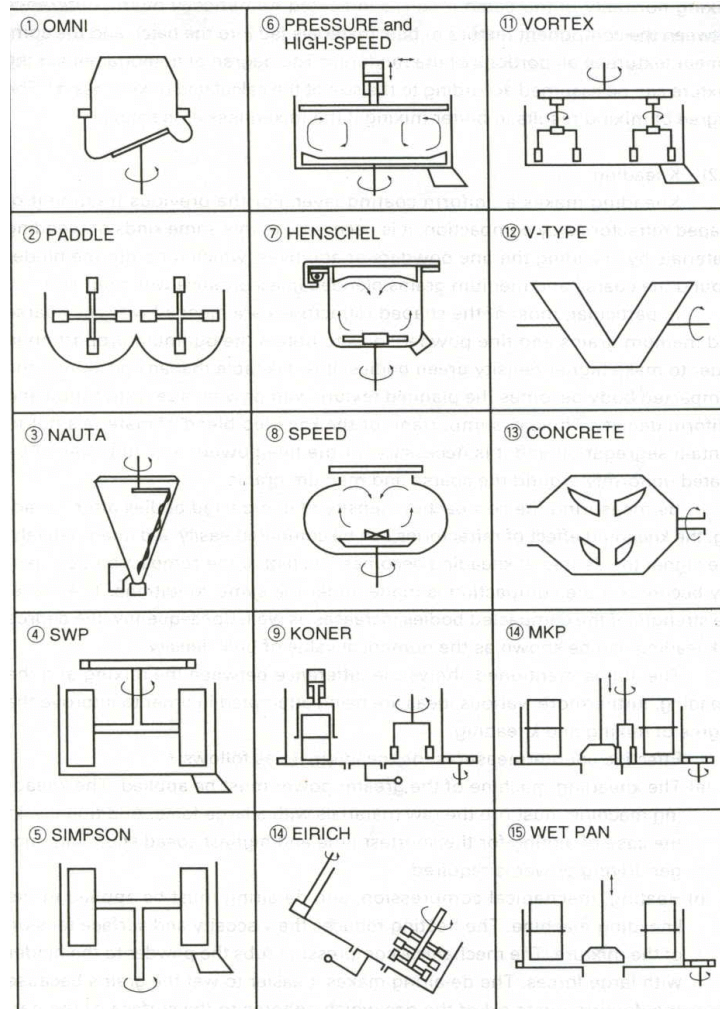


Figure 2-2. Mixing and Kneading Machines

- **Vibrating Press:** Vibrating presses, shown in Figure 2-5, are classified into two types: air cylinder type and hydraulic cylinder. The vibrator in the air cylinder type is attached to the table, and the air cylinder compacts the material. The hydraulic vibrating press is constructed with the hydraulic pulse generator attached to the pressure block, and the hydraulic cylinder compacts the material. Vibrating presses are typically used for the compaction of complexly shaped refractories (The Technical Association of Refractories, Japan, 1998).
- **Cold Isostatic Press (CIP):** A CIP, illustrated in Figure 2-6, is a molding device that provides homogeneous hydrostatic pressure over the entire surface of a rubber mold filled with powder. This method, also referred to as a hydrostatic press or a

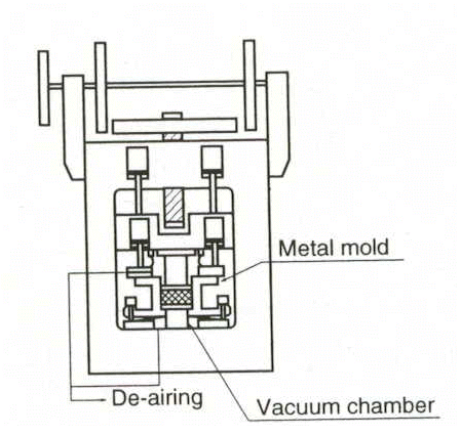


Figure 2-3. Vacuum Press (Friction, Hydraulic Press)

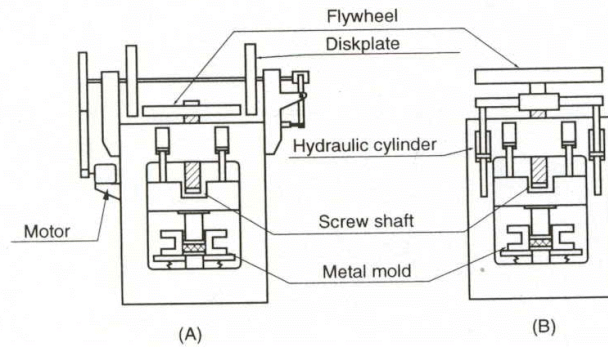


Figure 2-4. Friction Press (A), and Hydraulic Screw Press (B)

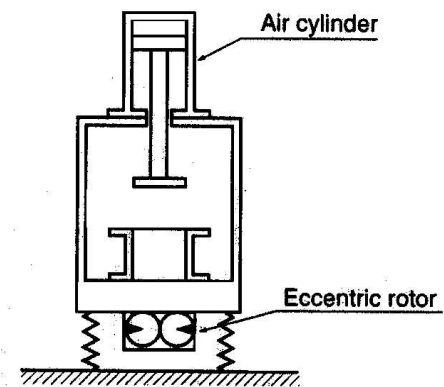


Figure 2-5. Vibrating Press

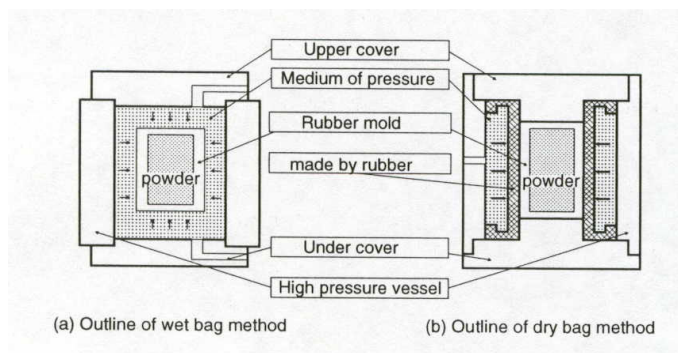


Figure 2-6. Cross Section of CIP

rubber press method, is a materials processing technique in which fluid pressure is applied to a powder part at ambient temperature to compact it into a predetermined shape. The powder part is consolidated into a dense compacted shape. Water or oil is usually used as the presser medium. CIPs are based on either the wet bag method, where the mold is placed in pressurized liquid, or the dry bag method, in which the mold does not touch the pressurized liquid. High pressurized molding provides uniform density, which leads to a reduction of internal stresses; the elimination of cracks, strains, and laminations; the ability to make complex shapes; and the ability to press more than one shape at the same time (The Technical Association of Refractories, Japan, 1998).

Kilns. Refractories are fired to develop the materials' refractory properties. The unfired ("green") refractories pass through a heat treatment, which results in a thermally stable refractory and or crystallization. The industry uses three types of kilns:

- **Tunnel Kiln:** In a tunnel kiln, refractory products consecutively pass through preheating, firing, and cooling zones (see Figure 2-7). The combustion gas from the firing zone is typically used to preheat the refractories. Heat can be recovered from cooling fired refractories and reused as combustion air. Approximately 80 percent of shaped refractories are fired in tunnel kilns (The Technical Association of Refractories, Japan, 1998).

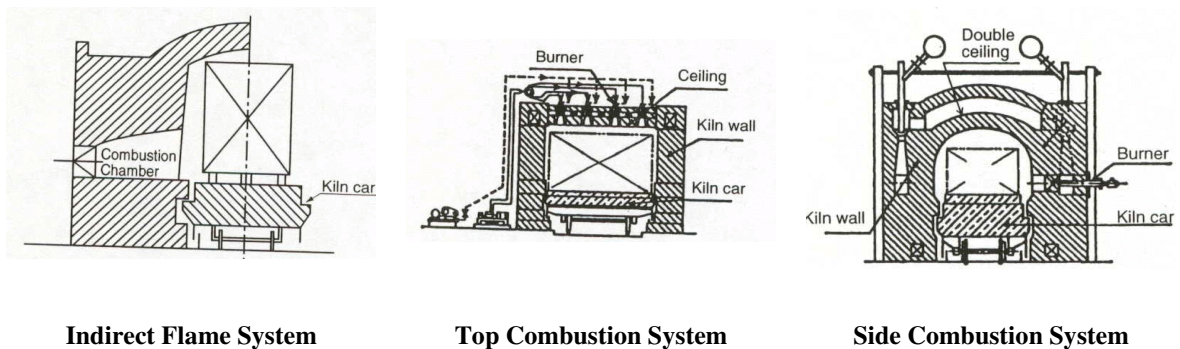


Figure 2-7. Tunnel Kiln

- **Round Periodic Kilns:** Round periodic kilns are typically used to fire silica bricks. Figure 2-8 is a diagram of a round periodic kiln. These kilns can be used to fire large refractory products that cannot be fired in a tunnel kiln and can easily accommodate changes in production (The Technical Association of Refractories, Japan, 1998).
- **Shuttle Kilns:** As illustrated in Figure 2-9, the design of a shuttle kiln resembles the firing zone of a tunnel kiln. Shuttle kilns effectively store heat and are used to fire fireclay and specialty bricks (The Technical Association of Refractories, Japan, 1998).

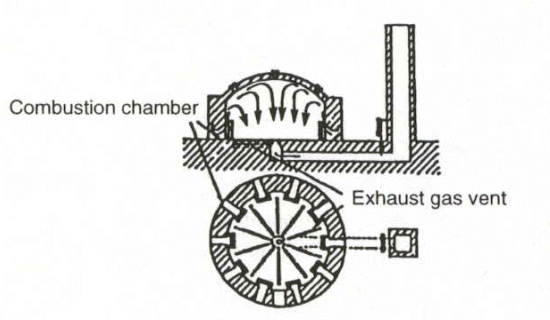


Figure 2-8. Round Kiln with Downdraft System

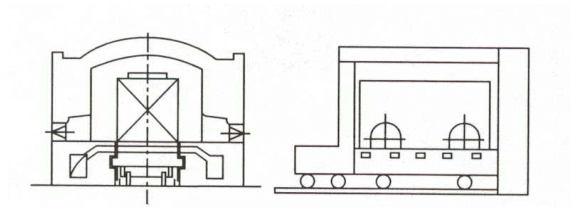


Figure 2-9. Shuttle Kiln

2.1.1.2 Final Commodities

Refractories are manufactured in two forms—shaped objects and unshaped, and unshaped refractories come in granulated or plastic compositions. Briefly described here, shaped and unshaped refractories are the two broad categories of refractories. Section 2.2 contains more information on the types of refractory products.

Shaped Refractories. Preshaped refractories include bricks, shapes, and crucibles. Shaped refractories are pre-fired to exhibit their ceramic characteristics. Table 2-1 lists each type of shaped refractory and a description of its use.

Unshaped Refractories. The unshaped products include mortars, gunning mixes, castables (refractory concrete), ramming mixes, and plastics. Unshaped refractories are often referred to as “monolithics.” The manufacture of unshaped refractories differs slightly from shaped refractories. Unshaped refractories typically do not go through a firing process until they reach the final consumer. These unshaped refractories can be installed by spraying, casting, molding, or ramming. Table 2-1 lists each type of refractory and a description of its use.

Table 2-1. Types and Descriptions of Refractories Produced

| Kind | Definition |
|---|--|
| Shaped Refractories | |
| Bricks | Refractories that have shapes and are used to line furnaces, kilns, glass tanks, incinerators, etc. |
| Insulating firebrick | Low thermal conductivity firebrick. |
| Unshaped Refractories (Monolithic) | |
| Mortar | Materials for bonding bricks in a lining. The three types of mortar—heat-setting, air-setting, and hydraulic-setting—have different setting mechanisms. |
| Castables | Refractories for which raw materials and hydraulic-setting cement are mixed. They are formed by casting and used to line furnaces, kilns, etc. |
| Plastics | Refractories in which raw materials and plastic materials are mixed with water. Plastic refractories are roughly formed, sometimes with chemical additives. |
| Gunning mixes | Refractories that are sprayed on the surface by a gun. |
| Ramming mixes | Granular refractories that are strengthened by gunning formulation of a ceramic bond after heating. Ramming mixes have less plasticity and are installed by an air rammer. |
| Slinger mixes | Refractories installed by a slinger machine. |
| Patching materials/ coating materials | Refractories with properties similar to refractory mortar. However, patching materials have controlled grain size for easy patching or coating. |
| Lightweight castables | Refractories in which porous lightweight materials and hydraulic cement are mixed. They are mixed with water and formed by casting. Lightweight castables are used to line furnaces, kilns, etc. |
| Fibrous Materials | |
| Ceramic fiber | Man-made fibrous refractory materials. There are several different types of ceramic fiber, including blanket, felt, module, vacuum form, rope, loose fiber, etc. |

Source: The Technical Association of Refractories, Japan. 1998. *Refractories Handbook*. Tokyo: The Technical Association of Refractories, Japan.

2.1.1.3 Emissions and Controls in Refractory Manufacturing

Refractory products manufacturing facilities are sources of several HAPs. At most refractory product manufacturing facilities, the primary sources of HAP emissions are the thermal process units, such as dryers, curing ovens, and kilns. The specific types and quantities of HAPs emitted from any particular facility are largely a function of the types of raw materials used and how those materials are processed. Among others, thermal process units used to produce resin-bonded, pitch-bonded, and pitch-impregnated bricks and shapes may be sources of HAP emissions. Resin-bonded refractory curing ovens and kilns can emit phenol, formaldehyde, methanol, and ethylene glycol, depending on the type of resin used. When used as binders or additives in the production of nonresin-bonded refractory shapes, ethylene glycol and methanol also are emitted from shape dryers and kilns. Pitch-bonded refractory heated pitch storage tanks, shape dryers, and kilns emit POM. The heated pitch storage tanks, shape preheaters, defumers, and coking ovens used to produce pitch-impregnated refractories also emit POM. Nearly all process units that are used to produce chromium refractory products emit chromium, and a small percentage of the chromium emitted from kilns that are used to fire chromium refractories is in the hexavalent form of chromium (Cr^{+6}). HF and HCl are emitted from kilns that are used to fire clay refractory products.

2.1.1.4 Inputs to Production of Refractory Products

The inputs in the production process for refractories include general inputs, such as labor, capital, and raw materials such as clay and nonclay materials. Two specific raw material inputs are discussed below.

Clays. Clay is composed mainly of fine particles of hydrous aluminum silicates and other minerals and is plastic when moist but hard when fired. In 1998, approximately 3.09 million tons (Mt) of clays were used in the manufacture of refractories. Table 2-2 lists different clays used in refractory products and their characteristics. Fireclay is the predominant clay used in firebrick; bentonite, in foundry sand; common clay, in refractory mortar and cement; and kaolin, in calcine, grog, high alumina brick, kiln furniture, and plug, tap, and wad (Virta, 1998).

Table 2-2. Types and Characteristics of Raw Materials used in Refractory Manufacture Type

| Type | Characteristics |
|-----------------------------|---|
| Clay Refractories | |
| Fireclay | Consists of kaolinite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) and minor amount of other clay materials. Fireclay refractories can be low, medium, high, or super-duty based on their resistance to high temperature or refractoriness. Fireclay refractories are used to produce bricks, insulating refractories, and two types of ladle brick. |
| High-alumina | Composed of bauxite or other raw materials that contain 50 to 87.5 percent alumina. High-alumina refractories are generally multipurpose, offering resistance to chipping and higher volume stability. High-alumina refractories are used to produce brick and insulating refractories. |
| Nonclay Refractories | |
| Basic | Produced from a composition of dead-burned magnesite, dolomite, chrome ore, and small amounts of other minerals. Basic refractories can be further subdivided into magnesia, dolomite, chrome, and combination bricks. Basic refractories are typically used to line kilns used to make bricks. |
| Extra-high alumina | Made predominately from bauxite or alumina (Al_2O_3), extra-high alumina refractories contain from 87.5 to 100 percent alumina and offer good volume stability. They are typically poured into special shapes using a fused casting process. |
| Mullite | Made from kyanite, sillimanite, andalusite, bauxite, or mixtures of alumina silicate materials; mullite refractories are about 70% alumina. They maintain a low level of impurities and high resistance to loading in high temperatures. |
| Silica | Silica refractories are characterized by a high coefficient of thermal expansion between room temperature and 500°C (930°F). Silica brick is available in three grades: super-duty (low alumina and alkali), regular, and coke oven quality. Silica compositions can be used for hot patching, shrouds, and bricks. |
| Silicon carbide | Produced by the reaction of sand and coke in an electric furnace, silicon carbide refractories are used to make special shapes, such as kiln furniture, to support ceramicware as it is fired in kilns. It has high thermal conductivity, good load bearing characteristics at high temperatures, and good resistance to changes in temperatures. |
| Zircon | Containing zirconium silicate ($\text{ZrO}_2 \cdot \text{SiO}_2$), zircon refractories maintain good volume stability for extended periods or exposure to high temperatures. Zircon refractories are widely used for glass tank construction. |

Nonclays. Nonclay refractories are composed for alumina, mullite, chromite, magnesite, silica, silicon carbide, zircon, and other nonclays. Table 2-2 lists various minerals used in the production of nonclay refractories, the type of refractory produced, and characteristics of the refractory.

2.1.2 Types of Products

Table 2-1 listed the different forms of refractories and describes them briefly. Refractories are generally categorized as either clay or nonclay products. To further classify the products, refractories are labeled as acidic or basic. Refractories are typically produced as shaped refractories, unshaped refractories, and fibrous materials. Shaped refractories include bricks, shapes, and crucibles. Bricks and shapes are formed by mixing raw materials with water and/or other binders and pressing or molding the mixture into a desired shape.¹ Crucibles are ceramic containers used for melting metal. Unshaped refractories, also called monolithics, are unformed products that are dried to form a unified structure after application. These refractories can be used as mortars, plastics, ramming mixes, castables, and gunning mixes. Monolithic refractories are applied by either pouring, pumping, troweling, or gunning (spraying).

2.1.3 Costs of Production

In the production process, the costs incurred by refractory manufacturers include labor, materials, and capital. This section provides data on these costs and discusses economies of scale.

2.1.3.1 Cost Data

Between 1994 and 1998, on average clay refractory manufacturers spent more than 70 percent of expenditures on input materials and nonclay refractory producers spent almost 64 percent. Figure 2-10 illustrates the percentage breakdown of refractory manufacturing expenditures by refractory type. Tables 2-3 and 2-4 also provide expenditures in dollars for wages, materials, and new capital from 1977 to 1998 in both current and 1997 dollars. Costs of materials include all raw materials, containers, scrap, and supplies used in production, repair, or maintenance during the year, as well as the cost of all electricity and fuel consumed. Costs are included for materials whether they are purchased from outside the company or transferred from within the company. New capital expenditures include permanent additions and alterations to

¹Refractory bricks and shapes can be formed by a variety of methods, including hand molding, air ramming, pressing, extruding, or casting.

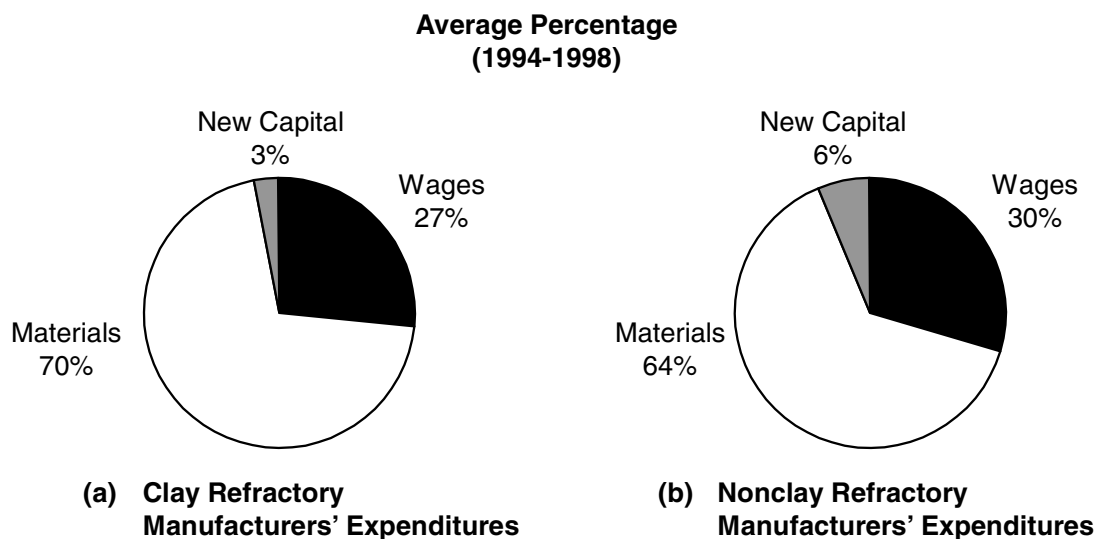


Figure 2-10. Clay and Nonclay Refractory Manufacturers' Expenditures

facilities and machinery and equipment used for expanding plant capacity or replacing existing machinery.

These tables show that the cost of materials is by far the greatest cost to refractory producers. Refractory producers spend as much as two and a half times more on materials than they do on labor. For 1998, the *Annual Survey of Manufactures* reported that the clay refractory industry spent \$31.6 million and the nonclay refractory industry spent \$52.7 million on energy, almost 6 and 8 percent, respectively, of the total materials cost for that year. Energy costs for manufacturers of refractory bricks and shapes are generally greater than energy costs for manufacturers of monolithic refractories because of the energy-intensive nature of operations that require using forming equipment, curing ovens, shape and cooking ovens, pitch and brick pre-heaters, dryers, and kilns. Table 2-5 contains a more detailed breakdown of the costs of materials used in producing and manufacturing refractory materials.

2.2 Industry Organization

This section examines the organization of the U.S. refractory industry, including plant location and production characteristics, commercial and captive producers, firm characteristics,

Table 2-3. Labor, Material, and New Capital Expenditures for Clay Refractory Manufacturers (NAICS 327124)^a (\$10⁶)

| Year | Wages | | Materials | | New Capital | |
|------|---------|--------|-----------|--------|-------------|-------|
| | Current | 1997\$ | Current | 1997 | Current | 1997 |
| 1977 | 146.8 | 224.30 | 296.8 | 453.48 | 20.0 | 30.56 |
| 1978 | 171.8 | 254.08 | 364.6 | 539.21 | 23.1 | 34.16 |
| 1979 | 191.5 | 273.16 | 384.7 | 548.74 | 29.4 | 41.94 |
| 1980 | 183.6 | 253.02 | 363.1 | 500.39 | 31.5 | 43.41 |
| 1981 | 199.6 | 266.09 | 410.6 | 547.37 | 36.1 | 48.12 |
| 1982 | 155.2 | 204.68 | 339.0 | 447.07 | 21.2 | 27.96 |
| 1983 | 147.1 | 191.19 | 358.5 | 465.94 | 12.0 | 15.60 |
| 1984 | 176.6 | 226.17 | 438.2 | 561.20 | 22.0 | 28.18 |
| 1985 | 166.8 | 211.69 | 397.5 | 504.47 | 22.1 | 28.05 |
| 1986 | 160.4 | 202.68 | 412.6 | 521.36 | 15.8 | 19.96 |
| 1987 | 150.2 | 188.05 | 387.5 | 485.15 | 11.7 | 14.65 |
| 1988 | 160.0 | 193.46 | 401.7 | 485.70 | 14.0 | 16.93 |
| 1989 | 176.7 | 207.39 | 451.3 | 529.69 | 11.9 | 13.97 |
| 1990 | 168.8 | 196.28 | 475.3 | 552.68 | 15.2 | 17.67 |
| 1991 | 166.0 | 191.22 | 464.8 | 535.40 | 18.5 | 21.31 |
| 1992 | 183.8 | 196.57 | 452.8 | 484.27 | 24.6 | 26.31 |
| 1993 | 163.9 | 180.42 | 377.0 | 415.00 | 7.2 | 7.93 |
| 1994 | 179.0 | 191.44 | 494.0 | 528.33 | 16.5 | 17.65 |
| 1995 | 199.0 | 205.37 | 510.3 | 526.63 | 16.6 | 17.13 |
| 1996 | 196.4 | 200.88 | 510.7 | 522.34 | 18.6 | 19.02 |
| 1997 | 210.0 | 210.42 | 566.0 | 567.13 | 30.1 | 30.16 |
| 1998 | 201.8 | 201.80 | 536.5 | 536.50 | 25.6 | 25.60 |

^a Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. 2001.
<<http://146.142.4.24/cgi-bin/surveymost>>.

Sources: U.S. Department of Commerce, Bureau of the Census. 1994b. *1992 Census of Manufactures, Industry Series—Cement and Structural Clay Products*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995. *1993 Annual Survey of Manufactures*. M93(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1996a. *1994 Annual Survey of Manufactures*. M94(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1997. *1995 Annual Survey of Manufactures*. M95(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1998. *1996 Annual Survey of Manufactures*. M96(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Census of Manufactures, Industry Series—Manufacturing: Clay Refractory Manufacturing*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 2000. *1998 Annual Survey of Manufactures*.

Table 2-4. Labor, Material, and New Capital Expenditures for Nonclay Refractory Manufacturers (NAICS 327125)^a (\$10⁶)

| Year | Wages | | Materials | | New Capital | |
|------|---------|--------|-----------|--------|-------------|-------|
| | Current | 1997 | Current | 1997 | Current | 1997 |
| 1977 | 134.3 | 205.20 | 336.4 | 513.99 | 37.1 | 56.69 |
| 1978 | 162.7 | 240.62 | 434.9 | 643.17 | 43.1 | 63.74 |
| 1979 | 172.5 | 246.05 | 434.6 | 619.91 | 24.4 | 34.80 |
| 1980 | 177.4 | 244.47 | 482.3 | 664.66 | 47.2 | 65.05 |
| 1981 | 196.5 | 261.95 | 484.7 | 646.15 | 69.7 | 92.92 |
| 1982 | 148.4 | 195.71 | 343.3 | 452.74 | 48.5 | 63.96 |
| 1983 | 129.5 | 168.31 | 312.8 | 406.55 | 20.8 | 27.03 |
| 1984 | 147.5 | 188.90 | 347.1 | 444.53 | 24.7 | 31.63 |
| 1985 | 152.0 | 192.90 | 369.2 | 468.55 | 32.5 | 41.25 |
| 1986 | 162.7 | 205.59 | 372.1 | 470.19 | 13.7 | 17.31 |
| 1987 | 202.5 | 253.53 | 443.5 | 555.26 | 16.3 | 20.41 |
| 1988 | 209.6 | 253.43 | 470.7 | 569.12 | 18.0 | 21.76 |
| 1989 | 232.6 | 273.00 | 480.4 | 563.85 | 36.3 | 42.61 |
| 1990 | 239.9 | 278.96 | 499.0 | 580.24 | 30.3 | 35.23 |
| 1991 | 241.3 | 277.95 | 500.6 | 576.64 | 26.5 | 30.53 |
| 1992 | 249.2 | 266.52 | 541.4 | 579.03 | 44.9 | 48.02 |
| 1993 | 279.3 | 307.45 | 578.8 | 637.14 | 62.5 | 68.80 |
| 1994 | 247.6 | 264.81 | 562.5 | 601.59 | 41.1 | 43.96 |
| 1995 | 274.9 | 283.70 | 588.3 | 607.13 | 35.9 | 37.05 |
| 1996 | 278.6 | 284.95 | 574.0 | 587.09 | 42.7 | 43.67 |
| 1997 | 288.4 | 288.98 | 621.3 | 622.54 | 88.8 | 88.98 |
| 1998 | 307.1 | 307.10 | 650.9 | 650.90 | 96.8 | 96.80 |

^a Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. 2001.
<<http://146.142.4.24/cgi-bin/surveymost>>.

Sources: U.S. Department of Commerce, Bureau of the Census. 1994a. *1992 Census of Manufactures, Industry Series—Abrasive, Asbestos, and Miscellaneous Mineral Products*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995. *1993 Annual Survey of Manufactures*. M93(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1996a. *1994 Annual Survey of Manufactures*. M94(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1997. *1995 Annual Survey of Manufactures*. M95(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1998. *1996 Annual Survey of Manufactures*. M96(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1999c. *1997 Census of Manufactures, Industry Series—Manufacturing: Nonclay Refractory Manufacturing*. Washington, DC: Government Printing Office.

Table 2-5. Costs of Materials Used in Refractory Production and Manufacture^a

| Material | 1997 | | 1992 | |
|---|--|---------------------------------|--|---------------------------------|
| | Delivered Cost (\$10 ⁶) | Percentage of Material Costs | Delivered Cost (\$10 ⁶) | Percentage of Material Costs |
| Clay NAICS 327124 | | | | |
| Materials, ingredients, containers, and supplies | 35.2 | 6.22 | 26.7 | 6.55 |
| Clay, ceramic, and refractory minerals | 284 | 50.18 | 209 | 51.26 |
| Dead-burned magnesia or magnesite | 6.9 | 1.22 | 8.4 | 2.05 |
| Refractories, clay or nonclay | 90.8 | 16.04 | 79.6 | 19.52 |
| Other stone, clay, glass, and concrete products | 4.4 | 0.78 | 5.2 | 1.28 |
| Industrial chemicals | 6.5 | 1.15 | 2.2 | 0.53 |
| All other materials and components, parts, containers, and supplies | 65.1 | 11.50 | 76.8 | 18.83 |
| Nonclay NAICS 327125 | | | | |
| Materials, ingredients, containers, and supplies | 50.4 | 8.11 | 65.4 | 11.12 |
| Clay, ceramic, and refractory minerals | 224.2 | 36.09 | 156.2 | 26.58 |
| Dead-burned magnesia or magnesite | 38.7 | 6.23 | 59.1 | 10.05 |
| Refractories, clay or nonclay | NA | NA | 65.6 | 11.16 |
| Other stone, clay, glass, and concrete products | NA | NA | NA | NA |
| Industrial chemicals | 21.4 | 3.44 | 21.1 | 3.58 |
| All other materials and components, parts, containers, and supplies | 73.9 | 11.89 | 75.3 | 12.82 |

NA = Not available.

^a Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. 2001.
<<http://146.142.4.24/cgi-bin/srgate>>.

Source: U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Census of Manufactures, Industry Series—Manufacturing: Clay Refractory Manufacturing*. Washington, DC: Government Printing Office.

market structure, and degree of integration. Understanding the industry's organization helps determine how it will be affected by complying with the refractory production NESHAP.

2.2.1 Refractory Manufacturing Facilities

A facility is a site of land with a plant and equipment that combine inputs (mineral products, organic and inorganic liquids, fuel and labor) to produce an output (refractory products). Companies that own these facilities are legal business entities that conduct transactions and make decisions that affect the facility. The terms "facility," "establishment," and "plant" are synonymous in this analysis and refer to the physical location where products are manufactured. Likewise, the terms "company" and "firm" are used interchangeably to refer to the legal business entity that owns one or more facilities. This section presents information on the companies that own refractory plants.

2.2.1.1 Refractories Database Facilities

Table 2-6 presents a list of 118 of the 167 refractory manufacturers obtained from a publicly available financial database, including the location of the facility, its estimated sales volume in millions of dollars, and its employment. This list includes many of the facilities potentially affected by the refractory products NESHAP, but does not correspond precisely with the set of facilities EPA believes may be affected, because data on those facilities were provided to EPA in confidential questionnaire responses. EPA's data indicate that the United States has 167 refractory manufacturing facilities.

2.2.1.2 Facility Location

Census data indicate that refractory materials are produced in 37 states. Table 2-7 lists the number of refractory facilities in the 50 states and Puerto Rico, based on the *Census of Manufactures*. The leading refractory-producing states are Pennsylvania and Ohio, which also contain a large number of steel mills. Figure 2-11 illustrates the distribution of the refractory-producing facilities in the United States, together with the location of plants in the industries that are the major consumers of refractory products. States with a large number of refractory plants typically also have substantial numbers of iron and steel, cement, and/or nonferrous metal plants, indicating that refractory plant location may depend at least in part on customer location. This is likely to be particularly true for unfired shaped refractories, because (they have not undergone firing) and are somewhat fragile and thus difficult to transport successfully.

Table 2-6. Selected Refractory Manufacturers, by Type

| Company | Location | Sales (\$10 ⁶) | Employment | Company Type | Owning Company | Sales (\$10 ⁶) | Employment |
|-----------------------------------|----------------------|----------------------------|------------|--------------|----------------------------------|----------------------------|------------|
| Clay | | | | | | | |
| Able Supply Co. | Houston, TX | NA | NA | NA | NA | NA | NA |
| Alsey Refractories Co. | Alsey, IL | 10 to 20 | 20 to 49 | Private | | | |
| B&B Refractories, Inc. | Santa Fe Springs, CA | 2.5 to 5 | 10 to 19 | Private | | | |
| Bay State Crucible Co. | Tauton, MA | 5 to 10 | 20 to 49 | Private | | | |
| Bloom Engineering Co., Inc. | Pittsburgh, PA | 38 | 187 | Subsidiary | Sterling Industries PLC, England | NA | NA |
| BNZ Materials, Inc. | Littleton, CO | 25 | 150 | Private | | | |
| Carpenter EPG Certech, Inc. | Wilkes Barre, PA | 14 | 150 | Subsidiary | Carpenter Technology Corp. | 1,000 | 5,324 |
| Carpenter Technology Corp. | Reading, PA | 1,000 | 5,324 | Public | | | |
| Ceradyne, Inc. | Costa Mesa, CA | 26 | 300 | Private | | | |
| Certech, Inc. | Wood Ridge, NJ | 62 | 758 | Subsidiary | Carpenter Technology Corp. | 1,000 | 5,324 |
| CFB Industries, Inc. | Chicago, IL | 23 | 176 | Private | | | |
| Christy Refractories Co. LLC | St. Louis, MO | 14 | 80 | Private | | | |
| Clay City Pipe | Uhrichsville, OH | 14 | 200 | Private | | | |
| Cooperheat-MQS, Inc. | Houston, TX | 120 | 1,200 | Private | | | |
| ER Advanced Ceramics, Inc. | East Palestine, OH | NA | NA | NA | NA | NA | NA |
| Ernhart Glass Manufacturing, Inc. | Owensville, NJ | NA | NA | NA | NA | NA | NA |
| Fels Refractories, Inc. | Edison, NJ | 1 to 2.5 | NA | Private | | | |
| Ferro Corp. | Cleveland, OH | 331 | 6,693 | Public | | | |
| Freeport Area Enterprises, Inc. | Freeport, PA | 10 | 150 | Private | | | |
| Freeport Brick Co. | Creighton, PA | NA | NA | NA | NA | NA | NA |

(continued)

Table 2-6. Selected Refractory Manufacturers, by Type (continued)

| Company | Location | Sales | | Company | | Sales | |
|--|--------------------|----------------------|------------|------------|---|----------------------|------------|
| | | (\$10 ⁶) | Employment | Type | Owning Company | (\$10 ⁶) | Employment |
| Clay (continued) | | | | | | | |
| Global Industrial Technologies, Inc. | Dallas, TX | 142 | 4,262 | Public | | | |
| Green AP Refractories, Inc. | Mexico, MO | 25 | 300 | Subsidiary | RHI AG | 1,580 | 14,500 |
| Harbison-Walker Refractories Co. | Pittsburgh, PA | 263 | 1,615 | Subsidiary | RHI AG | 1,580 | 14,500 |
| Heater Specialists, Inc. | Tulsa, OK | 17 | 160 | Private | | | |
| Holland Manufacturing Corp. | Dolton, IL | 2.5 to 5 | 20 to 49 | NA | NA | NA | NA |
| Howmet Corp. | Whitehall, MI | 1,300 | 10,350 | Subsidiary | Cordant Technologies, Inc. | 2,513 | 17,200 |
| Industrial Ceramic Products, Inc. | Columbus, OH | NA | NA | NA | NA | NA | NA |
| Industrial Product International | Englewood, CO | 1 to 2.5 | 5 to 9 | Private | | | |
| Inland Enterprise, Inc. | Avon, OH | 14 | 100 | Private | | | |
| Insul Co., Inc. | East Palestine, OH | 15 | 77 | Private | | | |
| International Chimney Corp. | Williamsville, NY | 18 | 140 | Private | | | |
| Louisville Firebrick Works | Graham, KY | NA | NA | NA | NA | NA | NA |
| Martin Marietta Magnesia Specialties, Inc. | Raleigh, NC | | | Subsidiary | Martin Marietta Materials, Inc. | 1,057 | 570 |
| Maryland Refractories Co. | Irondale, OH | 1 to 2.5 | NA | Private | | | |
| Mono Ceramics, Inc. | Benton Harbor, MI | 11 | 45 | Subsidiary | Monocon International Refractories, England | NA | NA |
| Morganite Crucible, Inc. | North Haven, CT | 15 | 75 | Subsidiary | Morgan Crucible Co. PLC, England | 1,394 | 16,885 |
| Mt. Savage Firebrick Co. | Frostburg, MD | NA | NA | NA | NA | NA | NA |
| National Refractories & Minerals Corp. | Livermore, CA | 115 | 600 | Subsidiary | National Refractory Holding Co., Inc. | NA | 810 |
| New Castle Refractories | Massillon, OH | 14 | 122 | Subsidiary | Dixon Ticonderoga | 115 | 1,354 |

(continued)

Table 2-6. Selected Refractory Manufacturers, by Type (continued)

| Company | Location | Sales (\$10 ⁶) | Employment | Company Type | Owning Company | Sales (\$10 ⁶) | Employment |
|--|---------------------|-------------------------------|------------|-----------------|-------------------------------------|-------------------------------|------------|
| Clay (continued) | | | | | | | |
| North America Refractories Co. | Cleveland, OH | 331 | 1,500 | Subsidiary | Didier-Werke AG, Germany | 448.5 | NA |
| P-G Industries, Inc. | Pueblo, CO | 12 | 160 | Private | | | |
| Plibrico Co. | Oak Hill, OH | 10 to 20 | 20 to 40 | Private | | | |
| Porvair Corp. | Hendersonville, NC | 18 | 200 | Private | | | |
| Premier Refractories, Inc. | King of Prussia, PA | 64 | 778 | Private | | | |
| Premier Refractories International, Inc. | King of Prussia, PA | 90 | 900 | Subsidiary | Alpine Group, Inc. | 1,370 | 6,600 |
| Pryotech, Inc. | Spokane, WA | 45 | 650 | Private | | | |
| Refco, Inc. | Boylston, MA | 34 | 88 | Subsidiary | Industrial Distribution Group, Inc. | 273 | 1,200 |
| Refractories Sales and Service Co., Inc. | Bessemer, AL | NA | NA | NA | NA | NA | NA |
| Reno Refractories, Inc. | Morris, AL | 16 | 85 | Private | | | |
| Resco Products, Inc. | Norristown, PA | 50 | 500 | Private | | | |
| RHI Refractories America | Pittsburgh, PA | NA | NA | NA | RHI Refractories AG | 1,580 | 14,500 |
| Riverside Clay Co., Inc. | Pell City, AL | 15 | 100 | | | | |
| Riverside Refractories, Inc. | Pell City, AL | 14 | 100 | Subsidiary | Riverside Clay Co., Inc. | 15 | 100 |
| Rutland Products | Jacksonville, FL | NA | NA | NA | NA | NA | NA |
| Servsteel, Inc. | Morgan, PA | | | | | | |
| SGL Carbon Corp. | Charlotte, NC | 255 | 1,891 | Subsidiary | SGL Aktiengesellschaft, Germany | | |
| Shenango Refractories, Inc. | New Castle, PA | 5 to 10 | 20 to 49 | Private | | | |
| Sterling Industries of Delaware, Inc. | Pittsburgh, PA | 57 | 312 | Subsidiary | Sterling Industries PLC, England | | |
| The Nock and Son Co. | Oak Hill, OH | 2.5 to 5 | 10 to 19 | Private | | | |

(continued)

Table 2-6. Selected Refractory Manufacturers, by Type (continued)

| Company | Location | Sales (\$10 ⁶) | Employment | Company Type | Owning Company | Sales (\$10 ⁶) | Employment |
|---------------------------------------|----------------------|----------------------------|------------|--------------|---------------------------------------|----------------------------|------------|
| Clay (continued) | | | | | | | |
| The Whitacre-Greer Fire Proofing Co. | Alliance, OH | 5 to 10 | NA | Private | | | |
| Thermal Ceramics, Inc. | Augusta, GA | 138 | 1,200 | Subsidiary | Morgan Crucible Co. PLC, England | 1,394 | 16,885 |
| Thorley Refractories, Inc. | Southgate, CA | 5 to 10 | 20 to 49 | Private | | | |
| Transit Mix Concrete Co., Inc. | Colorado Springs, CO | 25 | 210 | Subsidiary | Continental Materials Corp., Delaware | NA | NA |
| TYK America, Inc. | Clairton, PA | 37 | 122 | Subsidiary | TYK Corp., Japan | 133.5 | NA |
| Unifrax Corp. | Niagara Falls, NY | 85 | 285 | Subsidiary | Kirkland Capital Partners LP | 90 | 808 |
| Universal Refractories, Inc. | Wampum, PA | 24 | 130 | Private | | | |
| Utah Refractories Co. | Lehi, UT | NA | NA | NA | NA | NA | NA |
| Wahl Refractories, Inc. | Fremont, OH | 17 | 68 | Subsidiary | Thermatex Corp. | 10 | 148 |
| Zero Refractories, Inc. | Taylor MI | 0.5 | 1 to 4 | Private | | | |
| Nonclay | | | | | | | |
| Advanced Ceramics Corp. | Cleveland, OH | 25 to 50 | NA | Private | | | |
| Advanced Ceramics International, Inc. | Cleveland, OH | 21 | 175 | Private | | | |
| Allied Mineral Products, Inc. | Columbus, OH | 56 | 240 | Private | | | |
| Alpine Group, Inc. | New York, NY | 1,370 | 6,600 | Public | | | |
| Aluminum Company of America (ALCOA) | Pittsburgh, PA | 15,300 | 103,500 | Public | | | |
| AMPAC | Amsterdam, NY | 13 | 100 | Private | | | |
| B S C Holding, Inc. | Shawnee Mission, KS | 23 | 15 | Private | | | |
| Baker Holding Co., Inc. | York, PA | 190 | 1,300 | Public | | | |
| Baker JE Co. | York, PA | 190 | 1,050 | Subsidiary | Baker Holding Co., Inc. | 190 | 1,300 |
| Bartley Crucible & Refractories, Inc. | Trenton, NJ | NA | NA | NA | NA | NA | NA |

(continued)

Table 2-6. Selected Refractory Manufacturers, by Type (continued)

| Company | Location | Sales (\$10 ⁶) | Employment | Company Type | Owning Company | Sales (\$10 ⁶) | Employment |
|---|--------------------|-------------------------------|------------|-----------------|---------------------------------|-------------------------------|------------|
| Nonclay (continued) | | | | | | | |
| Bethlehem Advanced Materials Corp. | Knoxville, TN | 14 | 110 | Subsidiary | The Bethlehem Corp. | 14 | 117 |
| Blash Precision Ceramics, Inc. (Texas United) | Houston, TX | 63 | 515 | Private | | | |
| BNZ Materials, Inc. | Zelenople, PA | 1 to 2.5 | 5 to 9 | private | | | |
| CCPI, Inc. | Blanchester, OH | 25 to 50 | NA | private | | | |
| Cercom, Inc. | Vista, CA | 11 | 76 | Private | | | |
| Certech, Inc. | Streetsboro, OH | 62 | 758 | Subsidiary | Carpenter Technology Corp. | 1,000 | 5,324 |
| CFB Industries, Inc. | Chicago, IL | 23 | 176 | Private | | | |
| Chicago Firebrick Co., Inc. | Chicago, IL | 18 | 58 | Private | | | |
| Coors Porcelain Co., Inc. | | 304 | 2,900 | Subsidiary | ACX Technologies, Inc. | 988 | 5,600 |
| Dixon Ticonderoga Co., Inc. | Lake Mary, FL | 85 | 1,562 | Public | | | |
| ETS Schaefer Corp. | Macedonia, OH | 13 | 195 | Subsidiary | Alumitech, Inc. | 21 | 210 |
| Foseco, Inc. | Cleveland, OH | 71 | 500 | Subsidiary | Foseco Holding BV, Netherlands | | |
| Global Industrial Technologies, Inc. | Dallas, TX | 142 | 4,262 | Public | | | |
| Harbison-Walker Refractories Co. | Pittsburgh, PA | 263 | 1,615 | Subsidiary | RHI AG | 1,580 | 14,500 |
| Insul Co., Inc. | East Palestine, OH | 15 | 77 | Private | | | |
| JW Hicks, Inc. | Merrellville, IN | 5 to 10 | 20 to 49 | NA | NA | NA | NA |
| Magneco, Inc. | Addison, IL | 19 | 150 | Subsidiary | Magneco/Metrel, Inc. | 34 | |
| Martin Marietta Magnesia Specialties, Inc. | Raleigh, NC | | | Subsidiary | Martin Marietta Materials, Inc. | 1,057 | 570 |
| Minco Acquisition Corp. | Midway, TN | 21 | 170 | Private | | | |
| Minco, Inc. | Midway, TN | 15 | 135 | Subsidiary | Minco Acquisition Corp. | 21 | 170 |
| Minerals Technologies, Inc. | New York, NY | 609 | 2,260 | Public | | | |
| Minteq International, Inc. | New York, NY | 205 | 1,800 | Subsidiary | Minerals Technologies, Inc. | 609 | 2,260 |

(continued)

Table 2-6. Selected Refractory Manufacturers, by Type (continued)

| Company | Location | Sales | | Company | | Sales | |
|--|---------------------|----------------------|------------|------------|---------------------------------------|----------------------|------------|
| | | (\$10 ⁶) | Employment | Type | Owning Company | (\$10 ⁶) | Employment |
| Nonclay (continued) | | | | | | | |
| Mitsubishi Cement Corp. | Ontario, CA | 74 | 619 | Subsidiary | Mitsubishi Materials Corp., Japan | 9,354 | 6,556 |
| Mixed Mineral Products, Inc. | Columbus, OH | NA | NA | NA | NA | NA | NA |
| Monofrax, Inc. | Falconer, NY | 50 to 100 | 250 to 499 | Private | | | |
| Morganite Crucible, Inc. | North Haven, CT | 15 | 75 | Subsidiary | Morgan Crucible Co. PLC, England | 1,394 | 16,885 |
| National Refractories & Minerals Corp. | Livermore, CA | 115 | 600 | Subsidiary | National Refractory Holding Co., Inc. | | |
| New Castle Refractories | Massillon, OH | 14 | 122 | Subsidiary | Dixon Ticonderoga | 115 | 1,354 |
| Newport Sand & Gravel Co., Inc. | Newport, NH | 13 | 100 | Private | | | |
| North American Refractories Co. | Cleveland, OH | 331 | 1,500 | Subsidiary | Didier-Werke AG, Germany | NA | NA |
| Norton Co., Inc. | Worcester, MA | 1,500 | 9,000 | Subsidiary | Saint-Gobain, France | 23,113 | 165,000 |
| Osram Sylvania, Inc. | Danvers, MA | 5,200 | 13,000 | Subsidiary | Siemens Corp. | | |
| Osram Sylvania Products, Inc. | Danvers, MA | 1,800 | 1,100 | Subsidiary | Siemens Corp. | | |
| Pell Industries | Grove City, PA | 5 to 10 | 20 to 49 | Private | | | |
| Prefromix Technologies LTD | Warren, OH | 10 | 75 | Private | | | |
| Premier Refractories International, Inc. | King of Prussia, PA | 90 | 900 | Subsidiary | Alpine Group, Inc. | 1,370 | 6,600 |
| Premier Services, Inc. | Bettsville, OH | NA | NA | NA | NA | NA | NA |
| Pyrotek Inc. | Spokane, WA | 50 to 100 | NA | Private | | | |
| Rex Roto Corp. | Fowlerville, MI | 14 | 80 | Private | | | |

(continued)

Table 2-6. Selected Refractory Manufacturers, by Type (continued)

| Company | Location | Sales (\$10 ⁶) | Employment | Company Type | Owning Company | Sales (\$10 ⁶) | Employment |
|---------------------------------------|--------------------|-------------------------------|------------|-----------------|----------------------------|-------------------------------|------------|
| Nonclay (continued) | | | | | | | |
| Saint-Gobain Advanced Materials Corp. | Louisville, KY | 533 | 3,300 | Subsidiary | Norton Co., Inc. | | |
| Selee Corp. | Hendersonville, NC | 5 | 190 | Subsidiary | Porvair PLC, England | | |
| Silicon Carbide Products, Inc. | Elmira, NY | 1 to 2.5 | 5 to 9 | Private | | | |
| Spar, Inc. | Jacksonville, FL | NA | NA | NA | NA | NA | NA |
| Thermalmat Corp. (Thermalite) | Fremont, OH | 10 | 148 | Private | | | |
| TYK America, Inc. | Clairton, PA | 37 | 122 | Subsidiary | TYK Corp., Japan | 133.5 | NA |
| UCAR Carbon Co. | Danbury, CT | 105 | 1,506 | Subsidiary | UCAR International, Inc. | 947 | 4,952 |
| Universal Refractories, Inc. | Wampum, PA | 24 | 130 | Private | | | |
| Varsal Instruments, Inc. | Warminster, PA | 15 | 224 | Private | | | |
| Vesuvius Crucible Co. | Champaign, IL | 400 | 2,500 | Subsidiary | Cookson Group PLC, England | 3,011 | 17,101 |
| Vesuvius USA Corp. | Champaign, IL | 400 | 1,600 | Subsidiary | Cookson Group PLC, England | 3,011 | 17,101 |
| Wulfrath Refractories, Inc. | Tarentum, PA | 22 | 115 | Private | | | |
| Zircar Products, Inc. | Florida, NY | 12 | 85 | Private | | | |
| Zircoa, Inc. | Solon, OH | 20 | 140 | Subsidiary | Didier-Werke AG, Germany | 448.5 | 4,717 |

NA = Not available.

Source: Dun & Bradstreet. 2000. *D&B Million Dollar Directory*. Series 2000. Bethlehem, PA: Dun & Bradstreet, Inc.

Note: The data used to analyze company impacts of the proposed NESHAP are similar but not identical to these data. The actual data used include confidential survey responses and thus cannot be made public.

Table 2-7. Number of Refractory Manufacturing Facilities by State

| State | Number of Refractory Plants | |
|----------------|-----------------------------|------------------------|
| | Clay (NAICS 327124) | Nonclay (NAICS 327125) |
| Alabama | 8 | |
| California | 10 | 6 |
| Georgia | 5 | 4 |
| Illinois | 7 | 7 |
| Indiana | | 7 |
| Kentucky | | 6 |
| Maryland | 4 | |
| Michigan | | 7 |
| Missouri | 9 | 3 |
| New York | | 3 |
| New Jersey | | 7 |
| North Carolina | | 2 |
| Ohio | 27 | 24 |
| Pennsylvania | 30 | 22 |
| Texas | 7 | |
| West Virginia | | 3 |
| Totals | 107 | 101 |

Source: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Census of Manufactures*. Washington, DC: Government Printing Office.

2.2.2 Capacity Utilization

Capacity utilization indicates how well the current facilities meet demand, which can be measured by the capacity utilization rate. A capacity utilization rate is the ratio of actual production volumes to full-capacity production volumes. For example, if an industry is producing as much output as possible without adding new floor space for equipment, the capacity utilization rate would be 100 percent. On the other hand, if under the same constraints the industry were only producing 75 percent of its maximum possible output, the capacity utilization rate would be 75 percent. On an industry basis, capacity utilization is highly variable from year to year depending on economic conditions. It is also variable on a company-by-company basis depending not only on economic conditions, but also on the company's strategic position, within its particular industry. While some

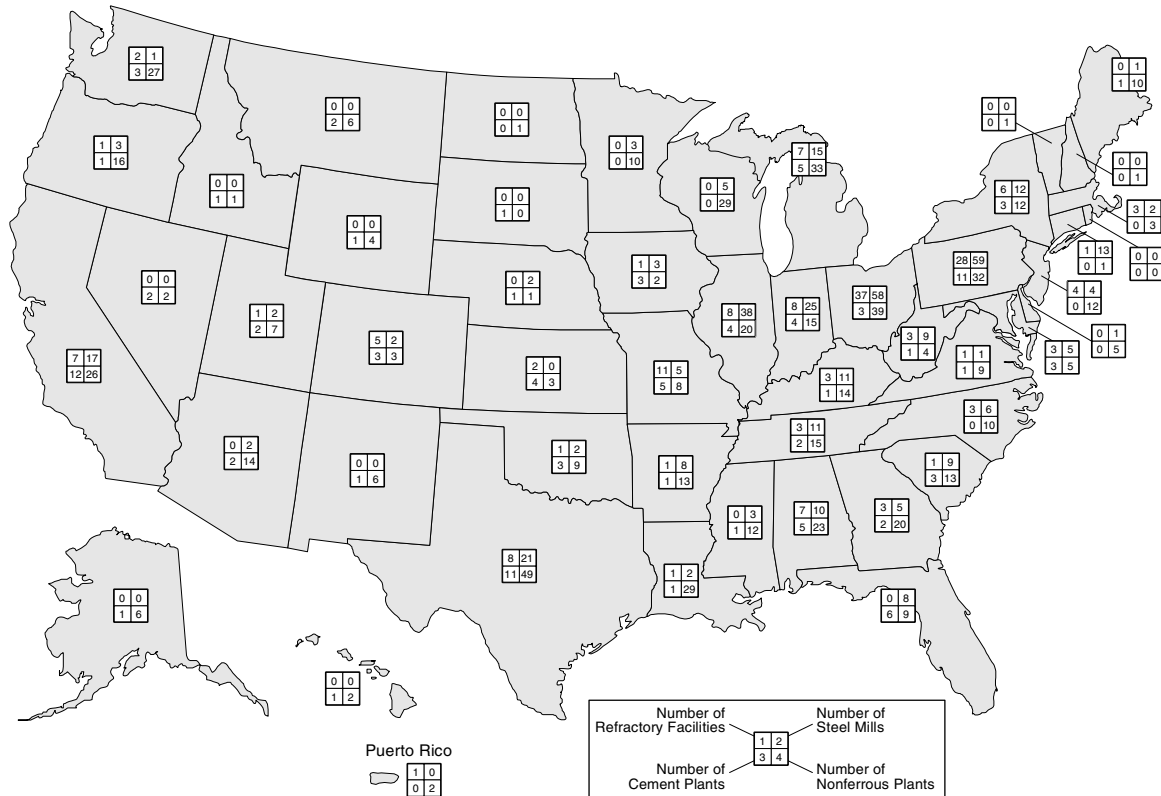


Figure 2-11. Location of Refractory Manufacturing Facilities

plants may have idle production lines or empty floor space, others need additional space or capacity.

Table 2-8 lists the capacity utilization rates for clay and nonclay refractory manufacturers for 1993 through 1998. Reduction in the demand for refractory replacements parts led to lower capacity utilization rates throughout this time period. Nonclay refractories, which include specialty refractory products, have seen increased demand, allowing that part of the industry to maintain an approximately 70 percent capacity utilization rate.

2.2.3 Industry Concentration and Market Structure

Market structure, which characterizes the level and type of competition among refractory producers, determines the behavior of producers and consumers in the industry, including their power to influence market price. If an industry is perfectly competitive, then the individual

Table 2-8. Full Production Capacity Utilization Rates for Clay and Nonclay Refractories: Fourth Quarters 1993 through 1998

| | Clay (NAICS 327125) | Nonclay (NAICS 327125) |
|------|---------------------|------------------------|
| 1993 | 75 | 71 |
| 1994 | 80 | 75 |
| 1995 | 63 | 81 |
| 1996 | 61 | 82 |
| 1997 | 49 | 78 |
| 1998 | 54 | 72 |

Source: U.S. Department of Commerce, Bureau of the Census. 1999d. *1998 Survey of Plant Capacity*. Washington, DC: Government Printing Office.

producers have little market power; they are not able to influence the price of the outputs they sell or the inputs they purchase. Perfectly competitive industries have large numbers of firms, the products sold are undifferentiated, and the entry and exit of firms are unrestricted.

Conversely, imperfectly competitive industries or markets are characterized by a smaller number of firms, differentiated products, and restricted entry or exit. Product differentiation can occur both from differences in product attributes and quality and from brand name recognition of products. Entry and exit of firms are restricted in industries when government regulates entry (e.g., through licenses or permits), when one firm owns the entire stock of critical input, or when a single firm is able to supply the entire market.

When compared across industries, firms in industries with fewer firms, more product differentiation, and restricted entry are more likely to have the power to influence the price they receive for a product by reducing output below perfectly competitive levels. At the extreme, a single monopolistic firm may supply the entire market and hence set the price of the output. On the input market side, firms may be able to influence the price they pay for an input if few firms, both from within and outside the industry, use that input.

2.2.3.1 Measures of Industry Concentration

To assess the competitiveness of an industry, economists often estimate four-firm concentration ratios (CR4), eight-firm concentration ratios (CR8), and Herfindahl-Hirschmann indexes (HHI) for the subject market or industry. The CR4s and CR8s measure the percentage of

sales accounted for by the top four and eight firms in the industry. The HHIs are the sums of the squared market shares of firms in the industry. Table 2-9 provides concentration ratios for the refractory industry.

Table 2-9. Market Concentration Measures for SIC 3255 Clay Refractory Manufacturing and SIC 3297 Nonclay Refractory Manufacturing

| Measure | Value | |
|--------------------------------------|-------|---------|
| | Clay | Nonclay |
| Herfindahl-Hirschmann Index (HHI) | 578 | 527 |
| Four-firm concentration ratio (CR4) | 40 | 36 |
| Eight-firm concentration ratio (CR8) | 62 | 58 |
| Number of companies | 95 | 102 |
| Number of facilities | 145 | 142 |
| Value of shipments | 886.8 | 1,203.8 |

Source: U.S. Department of Commerce, Bureau of the Census. 1996b. *Concentration Ratios in Manufacturing*. MC92-S-2. Washington, DC: Government Printing Office. Available at <<http://www.census.gov/mcd/mancen/download/mc92cr.sum>>.

Unfortunately, there is no objective criterion for determining market structure based on the values of these concentration ratios. However, there are criteria for determining market structure based on the HHIs for use in merger analyses, which are provided in the 1992 Department of Justice's Horizontal Merger Guidelines (U.S. Department of Justice and the Federal Trade Commission, 1992). According to these criteria, industries with HHIs below 1,000 are considered unconcentrated (i.e., more competitive), those with HHIs between 1,000 and 1,800 are considered moderately concentrated (i.e., moderately competitive). Firms in less-concentrated industries are more likely to be price takers, while firms in more-concentrated industries are more likely to be able to influence market prices. These measures of market concentration can be computed using four-digit SIC codes based on U.S. Bureau of the Census data (U.S. Department of Commerce, 1993). Based on the HHI criteria, the refractory industry is not concentrated, and, therefore, competitive in structure. These indices are measures of concentration of the industry at the national level. There is no reason to believe, however, that the markets for refractories may be regional rather than national.

2.2.3.2 Market Structure

The refractories industry is characterized by having the majority of its products used as inputs for the steel industry. The relatively small numbers of steel companies that are prominent users of refractory products may result in the buyers maintaining some measure of control over the input price (monopsony or oligopsony).

A monopsony occurs when a firm is the sole purchaser of an input. The monopsonist has the market power in the input market and can reduce the price paid without losing all input. An oligopsony is characterized by the presence of a few large buyers (even though there may also be many small buyers of insignificant size). In oligopsony, large firms are aware of their competitors for purchasing inputs and determine their purchasing price and quantity based on their expectations of their competitors' behavior. Although there may be some degree of market power exerted by steel companies on the demand side of the refractories market, our analysis treats the markets for refractory products as competitive. A sensitivity analysis is presented in Appendix B using a full-cost absorption approach, to assess the impacts if in fact steel companies have oligopsony power and refractory product manufacturers are unable to change price in response to higher costs.

2.2.3.3 Small Businesses that Own Refractory Facilities

To determine the possible impacts on small businesses, both clay and nonclay refractory manufacturers are categorized as small or large using the Small Business Administration (SBA) general size definitions (SBA, 1998). For clay refractory manufacturers, a small company has 500 or fewer employees. For nonclay refractory manufacturers, small is defined as having 750 or fewer employees.

Table 2-10 lists the employment and sales data for small companies that are owners of refractory-producing facilities. Again as in Table 2-6, these data are based on information available from publicly available sources. EPA's database provides information on company size, and its analysis of small business impacts is based on the best data currently available about the size of companies owning refractory products manufacturing facilities, including both questionnaire responses and publicly available information. To avoid revealing confidential questionnaire data, however, we present only the publicly available data in this section. Data on employment and sales for many of these companies are difficult to acquire from public sources, because they are privately held. These data suggest that a total of 59 small businesses own 76 facilities that produce refractory products. These are shown in Table 2-10.

Table 2-10. Characteristics of Small Businesses in the Refractory Industry

| Company | Location | Sales (\$10⁶) | Employment | Organization Type |
|---|----------------------|-------------------------------------|-------------------|------------------------------|
| Able Supply Co. | Houston, TX | NA | NA | NA |
| Alsey Refractories Co. | Alsey, IL | 10 to 20 | 20 to 49 | Private |
| B&B Refractories Inc. | Santa Fe Springs, CA | 2.5 to 5 | 10 to 19 | NA |
| Bay State Crucible Co. | Taunton, MA | 5 to 10 | 20 to 49 | NA |
| Ceradyne Inc. | Costa Mesa, CA | 26 | 300 | Private |
| Christy Refractories Co. LLC | St. Louis, MO | 14 | 80 | Private |
| Clay City Pipe ^a | Uhrichsville, OH | 14 | 200 | Private |
| ER Advanced Ceramics Inc. | East Palestine, OH | NA | NA | NA |
| Ermhart Glass Manufacturing Inc. | Owensville, NJ | NA | NA | NA |
| Fels Refractories Inc. | Edison, NJ | 1 to 2.5 | NA | Private |
| Freeport Area Enterprises Inc. ^a | Freeport, PA | 10 | 150 | Private |
| Freeport Brick Co. | Creighton, PA | NA | NA | NA |
| Heater Specialists, Inc. ^a | Tulsa, OK | 17 | 160 | Private |
| Holland Manufacturing Corp. | Dolton, IL | 25 to 5 | 20 to 49 | Private |
| Industrial Ceramic Products Inc. | Columbus, OH | NA | NA | NA |
| Industrial Product International | Englewood, CO | 1 to 2.5 | 5 to 9 | Private |
| Inland Enterprise Inc. | Avon, OH | 14 | 100 | Private |
| International Chimney Corp. ^a | Williamsville, NY | 18 | 140 | Private |
| Louisville Firebrick Works | Graham, KY | NA | NA | NA |
| Maryland Refractories Co. | Irondale, OH | 1 to 2.5 | NA | Private |
| Mt. Savage Firebrick Co. | Frostburg, MD | NA | NA | NA |
| P-G Industries Inc. | Pueblo, CO | 12 | 160 | Private |
| Plibrico Co. | Oak Hill, OH | 10 to 20 | 20 to 49 | NA |
| Porvair PLC | United Kingdom | 88.2 | 658 | Public |
| Refractories Sales and Service Co. Inc. | Bessemer, AL | NA | NA | NA |
| Reno Refractories Inc. | Morris, AL | 16 | 85 | Private |
| Resco Refractories, Inc. | Norristown, PA | 50 | 500 | Private |
| Riverside Clay Co. Inc. | Pell City, AL | 15 | 100 | NA |
| Rutland Products | Jacksonville, FL | NA | NA | NA |

(continued)

Table 2-10. Characteristics of Small Businesses in the Refractory Industry (continued)

| Company | Location | Sales (\$10⁶) | Employment | Organization Type |
|--|------------------------|-------------------------------------|-------------------|------------------------------|
| Servsteel Inc. | Morgan, PA | | | |
| Shenango Refractories, Inc. | New Castle, PA | 5 to 10 | 20 to 49 | Private |
| Nock and Son Co., The | Oak Hill, OH | 2.5 to 5 | 10 to 19 | Private |
| Whitacre-Greer Fire Proofing Co., The | Alliance, OH | 5 to 10 | NA | Private |
| Thorley Refractories Inc. | Southgate, CA | 5 to 10 | 20 to 49 | Private |
| Utah Refractories Co. | Lehi, UT | NA | NA | NA |
| Zero Refractories, Inc. | Taylor MI | 0.5 to 1 | 1 to 4 | Private |
| BNZ Materials Inc. | Littleton, CO | 25 | 150 | Private |
| CFB Industries Inc. ^a | Chicago, IL | 23 | 176 | Private |
| Insul Co. Inc. | East Palestine, OH | 15 | 77 | Private |
| Pyrotek Inc. ^a | Spokane, WA | 50 to 100 | NA | Private |
| Thermatex Corp. (Thermalite) | Fremont, OH | 10 | 148 | Private |
| Universal Refractories Inc. | Wampum, PA | 24 | 130 | Private |
| Advanced Ceramics ^a International Inc. | Cleveland, OH | 21 | 175 | Private |
| Allied Mineral Products Inc. | Columbus, OH | 56 | 240 | Private |
| Alumitech Inc. ^a | Canada | 77 | 447 | Public |
| AMPAC ^a | Amsterdam, NY | 13 | 100 | Private |
| B S C Holding Inc. ^a | Shawnee Mission, KS | 23 | 15 | Private |
| Bartley Crucible & Refractories, Inc. | Trenton, NJ | NA | NA | NA |
| Blash Precision Ceramics, Inc. (Texas United) | Houston, TX | 63 | 515 | Private |
| CCPI Inc. | Blanchester, OH | 25 to 50 | NA | Private |
| Cercom Inc. ^a | Vista, CA | 11 | 76 | Private |
| Chicago Firebrick Co. Inc. ^a | Chicago, IL | 18 | 58 | Private |
| JW Hicks Inc. | Merrellville, IN | 5 to 10 | 20 to 49 | Private |
| Magneco/Metrel Inc. | Addison, IL | 34 | 150 | Private |
| Minco Acquisition Corp. ^a | Midway, TN | 21 | 170 | Private |

(continued)

Table 2-10. Characteristics of Small Businesses in the Refractory Industry (continued)

| Company | Location | Sales (\$10⁶) | Employment | Organization Type |
|--|------------------|-------------------------------------|-------------------|------------------------------|
| Mixed Mineral Products Inc. ^a | Columbus, OH | NA | NA | NA |
| Monofrax Inc. ^a | Falconer, NY | 50 to 100 | 250 to 499 | Private |
| Newport Sand & Gravel Co. Inc. ^a | Newport, NH | 13 | 100 | Private |
| Pell Industries | Grove City, PA | 5 to 10 | 20 to 49 | Private |
| Prefromix Technologies LTD ^a | Warren, OH | 10 | 75 | Private |
| Premier Services, Inc. | Bettsville, OH | NA | NA | NA |
| Rex Roto Corp. | Fowlerville, MI | 14 | 80 | Private |
| Silicon Carbide Products Inc. | Elmira, NY | 1 to 2.5 | 5 to 9 | NA |
| Spar, Inc. | Jacksonville, FL | NA | NA | NA |
| Bethlehem Corporation, The ^a | Easton, PA | 14 | 117 | Private |
| Varsal Instruments Inc. ^a | Warminster, PA | 15 | 224 | Private |
| Wulfrath Refractories Inc. | Tarentum, PA | 22 | 115 | Private |
| Zircar Products Inc. | Florida, NY | 12 | 85 | Private |

^a These companies were listed by Ward's Business Directory under the NAICS codes 327124 and 32712. However, they were not linked to a facility in the database. These companies are ignored in the remaining small business analysis.

In its analysis of small business impacts, EPA has chosen to use a small business size criterion of 750 employees regardless of the primary NAICS code of the company. EPA made this decision because some companies in the industry produce both clay and nonclay refractories, making it difficult to assign such companies to a single NAICS code. Using the higher 750 employee small business criterion for all affected companies may overstate the number of small businesses affected by the proposed rule. EPA has obtained company employment and sales data from potentially regulated facilities, some of which is confidential. Based on this information and a small business size criterion of 750 employees, EPA has identified 60 small businesses that are potentially affected by the proposed NESHAP, out of a total of 81 companies owning refractory manufacturing facilities.

2.2.4 Current Trends in the Refractory Industry

To remain competitive, refractory manufacturers have continued to improve raw materials and manufacturing and testing processes. The trend toward increased lining life in most applications

has reduced the costs of repair and replacement to refractory consumers. Improvements in the production process of steel, glass, and petrochemicals in combination with improvements in refractory products and linings have culminated to reduce the amount of refractory consumption. Recently, the basic oxygen steelmaking furnace linings have exceeded 20,000 heats. The glass industry has experienced increased time between repairs in glass furnaces from every 4 years to 13 years, with little or no preventative maintenance (Sheppard, 2000; *Ceramic Industry*, 2000). From 1998 to 1999, the refractory industry reported a 6 percent decline in production and a 12 percent decline in turnover (DHAN, 1999).

Because of improved quality of refractory products and the availability of cheaper refractory imports, the steel industry has decreased consumption of refractories from 25 to 30 kg per ton of steel to 10 kg in Japan and the United States (Semler, 2000). This is the result of increased life span of refractory products. Other consumers of refractory products, including the petroleum industry and concrete industry, are following the steel industry's pattern of reducing consumption of refractories.

2.3 The Demand Side

Estimating the economic impacts of the regulation on the refractory manufacturing industry requires characterizing various aspects of the demand for refractory products. This section describes the product characteristics desired by end users; the uses for refractories, including use in the glass, metal, and electronics industries; and possible substitutes for refractories.

2.3.1 Product Characteristics

Because the quality and characteristics of refractories vary considerably, consumers often employ chemical and physical tests to ensure that the refractories purchased meet their requirements. The American Society for Testing and Materials (ASTM) provides specifications and tests for various kinds and uses of refractory products. Depending on the intended end use, consumers may test refractories for thermal conductivity, resistance to abrasion and corrosion, permeability, oxidation resistance, pyrometric cone equivalence, and other characteristics (ASM International, 1987).

Most refractory products are sold as preformed shapes. However, they are also available in special purpose clays; bonding mortars; and monolithic, plastic refractories; ramming mixes; and gunning mixes. A variety of processed refractory grains and powders are also produced (DHAN, 1999). From the physical form, refractory products can be further classified into oxide bricks,

nonoxide bricks, and composites. Table 2-11 lists types of oxide, nonoxide, and composite refractories; their characteristics; and their applications.

2.3.2 Uses and Consumers

Principle end-use markets for refractory products include the iron and steel, cement, and nonferrous metal industries. The steel industry consumes the largest percentage of refractories, estimated between 50 and 80 percent of the refractory production (Semler, 2000).² Table 2-12 presents metric ton production of raw steel and nonferrous metals for the period 1994 to 1999. Refractory products are used in the steel industry to line coke ovens, blast furnaces, blast furnace stoves, basic oxygen vessels, electric furnaces, open-hearth furnaces, and other heat-related manufacturing equipment (ASM International, 1987). As described above, refractory products are used by steel, cement and nonferrous metals producers. Refractory products manufacturing facilities are typically located close to their consumers (see map in Figure 2-11).

2.3.3 Substitution Possibilities in Consumption

Although there is no direct substitute for refractories, industries that use refractory products have reduced the amount of the product consumed. Since the 1980s, the steel industry has closed inefficient facilities and modernized remaining plants. The industry developed and implemented technologies, such as the basic oxygen furnace (BOF), that significantly reduced the amount of refractories used per ton of steel (USITC, 1994; DHAN, 1999). Also, the refractory industry has made significant strides in developing more durable refractories. These two factors have reduced the overall consumption of refractory materials.

2.4 Markets for Refractory Products

This section provides data on domestic production, domestic consumption, imports, exports of refractories, and gross margin growth in prices. It also discusses trends and projections for the refractory industry.

²The U.S. International Trade Commission (USITC) estimated consumption of the steel industry at over 50 percent, and DHAN estimated it at 75 percent.

Table 2-11. Characteristics and Types of Refractories

| Refractory Type | General Characteristics | Application |
|-------------------------|---|--|
| Oxide Bricks | | |
| Silica | High strength at high temperatures, residual expansion, low specific gravity, high expansion coefficient at low temperatures, low expansion coefficient at high temperatures | Glass tank crown, copper refining furnace, electric arc furnace roof |
| Fused silica | Low thermal expansion coefficient, high thermal shock resistance, low thermal conductivity, low specific gravity, low specific heat | Coke oven, hot stove, soaking pit, glass tank crown |
| Chamotte (fireclay) | Low thermal expansion coefficient, low thermal conductivity, low specific gravity, low specific heat, low strength at high temperatures, less slag penetration | Ladle, runner, sleeve, coke oven, annealing furnace, blast furnace hot stove, reheating furnace, soaking pit |
| Alumina | High refractoriness, high mechanical strength, high slag resistance, high specific gravity, relatively high thermal conductivity | Hot stove, stopper head, sleeve, soaking pit cover, reheating furnace, glass tank, high-temperature kiln |
| High alumina | High refractoriness, high mechanical strength, high slag resistance, high specific gravity, relatively high thermal conductivity | Slide gate, aluminum melting furnace, skid rail, ladle, incinerator, reheating furnace hearth, skid rail, ladle, incinerator |
| Roseki | Low thermal expansion coefficient, high thermal shock resistance, low thermal conductivity, low specific gravity, low specific heat | Ladle, runner, sleeve, coke oven, annealing furnace, blast furnace hot stove, reheating furnace, soaking pit |
| Zircon | High thermal shock resistance, high slag resistance, high specific gravity | Ladle, nozzle, stopper head, sleeve |
| Zirconia | High melting point, low wettability against molten metal, low thermal conductivity, high corrosion resistance, high specific gravity | Nozzle for continuous casting, glass tank, high-temperature furnace, crucible |
| Alumina zirconia silica | High slag resistance, high corrosion resistance against molten glass | Glass tank, incinerator, ladle, nozzle for continuous casting |
| Lime | High slag resistance, low hydration resistance | Special refining surface |
| Magnesia | High refractoriness, relatively low strength at high temperature, high basic slag resistance, low thermal shock resistance, low durability at high humidity | Hot-metal mixer, secondary refining vessel, rotary kiln, checker chamber of glass tank, electric arc furnace |
| Magnesia-chrome | High refractoriness, high refractoriness under load, high basic slag resistance, relatively good thermal shock resistance (low MgO bricks), high strength at high temperature (direct bonded and fusion cast) | Hot-metal mixer, electric arc furnace, secondary refining vessel, nonferrous refining furnace, rotary cement kiln, lime and dolomite kiln, copper furnace, ladle, checker chamber for glass tank, slag line of electric arc furnace, degasser for copper, nonferrous smelter |

(continued)

Table 2-11. Characteristics and Types of Refractories (continued)

| Refractory Type | General Characteristics | Application |
|---------------------------------|--|---|
| Oxide Bricks (continued) | | |
| Chrome | High refractoriness, low strength at high temperature, low thermal resistance | Buffer brick between acid and basic brick |
| Dolomite | High refractoriness, high refractoriness under load, high basic slag resistance, low durability in high humidity, high thermal expansion coefficient | Basic oxygen furnace, electric arc furnace, secondary refining vessel, rotary cement kiln |
| Spinel | High thermal shock resistance, high strength at high temperatures, high slag resistance | Rotary cement kiln, ladle |
| Nonoxide Bricks | | |
| Carbon | High refractoriness, high slag resistance, low oxidation resistance | Blast furnace hearth, electric arc furnace |
| Silicon carbide | High refractoriness, high strength at high temperature, high thermal conductivity, high thermal shock resistance, reduced oxidation resistance at high temperature, high slag resistance | Kiln furniture, incinerator, blast furnace |
| Silicon carbide-graphite | High refractoriness, high strength at high temperature, high thermal conductivity, high thermal shock resistance | Incinerator |
| Silicon nitride | High strength, high thermal shock resistance, relatively high oxidation resistance | Kiln furniture, blast furnace |
| Composite | | |
| Silicon carbide Containing | High corrosion resistance against low iron oxide, high strength at high temperatures, high thermal shock resistance | Ladle, blast furnace, electric arc, torpedo ladle, iron ladle |
| Magnesia-carbon | High slag resistance, high thermal shock resistance | Basic oxygen furnace, electric arc furnace, ladle |
| Alumina-carbon | High refractoriness, high thermal shock resistance, high corrosion resistance | Submerged entry nozzle, slide gate |

Source: The Technical Association of Refractories, Japan. 1998. *Refractories Handbook*. Tokyo: The Technical Association of Refractories, Japan.

2.4.1 Market Data

This section provides data on volumes of refractory products produced and consumed in the United States, the quantities imported and exported, and prices. Figure 2-12 illustrates historic trends in refractory production.

Table 2-12. Steel and Nonferrous Production (10³ Metric Tons)

| Year | Raw Steel Production | Nonferrous |
|------|----------------------|------------|
| 1994 | 91,300 | 11,216 |
| 1995 | 95,200 | 13,606 |
| 1996 | 94,700 | 11,608 |
| 1997 | 98,500 | 14,501 |
| 1998 | 98,700 | 14,811 |
| 1999 | 95,300 | 15,215 |

Source: U.S. Department of Commerce, and International Trade Administration. 1999. *U.S. Industry & Trade Outlook 2000*. New York: The McGraw-Hill Companies and U.S. Department of Commerce.

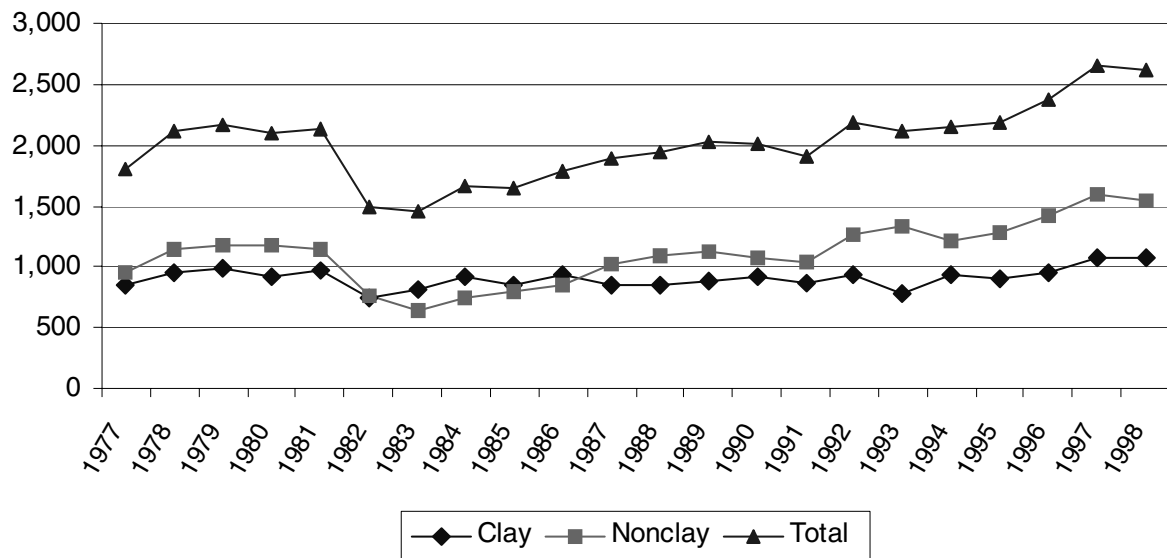


Figure 2-12. Historical Refractory Production Trends

Note: All financial figures are adjusted for inflation using the producer price index available from the U.S. Bureau of Labor.

2.4.1.1 Domestic Production

During the last two decades, the refractory industry has been affected by declining demand per production of steel for traditional refractory products, such as bricks and shapes, and customer requirements for higher-quality special refractories. Accounting for nearly 40 percent of all shipments, bricks and shapes are the principal forms of refractory products produced in the United States (USITC, 1993). Table 2-13 illustrates the values of domestically produced clay and nonclay refractories from 1977 to 1998 in both current and 1998 dollars.

2.4.1.2 International Trade

As indicated in Table 2-14, international trade is not a major component of the U.S. market for refractory products. In 1999, refractory exports accounted for a little over 16 percent of shipped refractory products. Nations with significant iron, steel, cement, and nonferrous metal industries, including the United States, Europe, and Japan, are the major world markets for refractory products. From 1988 to 1992, Canada was the leading importer of U.S. refractory products, with over 38 percent of all exports, followed by Mexico. Emerging foreign markets for the United States include India, China, and other countries in Central and South America. Japan and Canada are the top suppliers of imports to the United States (USITC, 1994).

2.4.2 Market Prices

Table 2-15 lists average prices for refractory products for 1989, 1993, and 1998. Monolithic refractory prices have decreased 2 percent and bricks and shapes have increased 4.8 percent since 1993. Most refractory products are typically used in kilns and ovens and are engineered for a particular use. Price is typically based on the consumer's requirements.

2.4.3 Industry Trends

In the last decade, the refractory industry has experienced significant restructuring. Two large conglomerates, RHI and Vesuvius, dominated refractories markets (Sheppard, 2000). In 1999, Alpine Group sold its Premier Refractories unit to Cookson Group of the U.K., and Global Industrial Technologies (parent of Harbison-Walker Refractories) was acquired by RHI AG (formerly Radex Heraklith Industriebeteiligungs) of Austria. Other leading refractory producers are Allied Mineral Products, Baker Refractories, Minerals Technologies (via MINTEQ), Morgan Crucible, National Refractories Holding Co., Resco Products, and Compagnie de Saint-Gobain.

Table 2-13. Production of Refractories: 1977–1998 (\$10⁶)

| Year | Clay | | Nonclay | | Total | |
|------|---------|---------|---------|---------|---------|---------|
| | Current | 1998 | Current | 1998 | Current | 1998 |
| 1977 | 607.2 | 848.9 | 680.2 | 950.9 | 1,287.4 | 1,799.8 |
| 1978 | 717.3 | 956.4 | 864.2 | 1,152.3 | 1,581.5 | 2,108.7 |
| 1979 | 776.9 | 983.5 | 934.9 | 1,183.5 | 1,711.8 | 2,167.0 |
| 1980 | 761.6 | 922.4 | 975.9 | 1,182.0 | 1,737.5 | 2,104.4 |
| 1981 | 864.2 | 976.0 | 1020.9 | 1,153.0 | 1,885.1 | 2,129.0 |
| 1982 | 670.3 | 738.4 | 691.0 | 761.2 | 1,361.3 | 1,499.5 |
| 1983 | 745.5 | 813.8 | 588.9 | 642.9 | 1,334.4 | 1,456.7 |
| 1984 | 868.6 | 920.1 | 701.4 | 743.0 | 1,570.0 | 1,663.1 |
| 1985 | 803.0 | 849.2 | 755.3 | 798.7 | 1,558.3 | 1,647.9 |
| 1986 | 843.5 | 931.4 | 768.5 | 848.6 | 1,612.0 | 1,780.0 |
| 1987 | 788.2 | 851.2 | 954.5 | 1,030.8 | 1,742.7 | 1,882.1 |
| 1988 | 836.7 | 851.0 | 1,078.1 | 1,096.5 | 1,914.8 | 1,947.5 |
| 1989 | 906.3 | 892.5 | 1,113.3 | 1,130.3 | 2,019.6 | 2,022.8 |
| 1990 | 922.9 | 927.0 | 1,077.6 | 1,082.4 | 2,000.5 | 2,009.5 |
| 1991 | 850.4 | 872.6 | 1,009.2 | 1,035.5 | 1,859.6 | 1,908.1 |
| 1992 | 886.8 | 930.6 | 1,203.5 | 1,263.0 | 2,090.3 | 2,193.6 |
| 1993 | 758.0 | 784.6 | 1,282.2 | 1,327.1 | 2,040.2 | 2,111.7 |
| 1994 | 938.8 | 929.5 | 1,232.2 | 1,220.0 | 2,171.0 | 2,149.5 |
| 1995 | 958.2 | 896.2 | 1,370.4 | 1,281.7 | 2,328.6 | 2,178.0 |
| 1996 | 977.3 | 953.6 | 1,459.4 | 1,424.0 | 2,436.7 | 2,377.6 |
| 1997 | 1,101.6 | 1,072.9 | 1,631.2 | 1,588.7 | 2,732.8 | 2,661.6 |
| 1998 | 1,082.8 | 1,082.8 | 1,535.8 | 1,535.8 | 2,618.6 | 2,618.6 |

Sources: U.S. Department of Commerce, Bureau of the Census. 1994b. *1992 Census of Manufactures, Industry Series—Cement and Structural Clay Products*. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. 1995. *1993 Annual Survey of Manufactures*. M93(AS)-1. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. 1996a. *1994 Annual Survey of Manufactures*. M94(AS)-1. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. 1997. *1995 Annual Survey of Manufactures*. M95(AS)-1. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. 1998. *1996 Annual Survey of Manufactures*. M96(AS)-1. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Census of Manufactures, Industry Series—Manufacturing: Clay Refractory Manufacturing*. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. 2000. *1998 Annual Survey of Manufactures*. M98(AS)-1. Washington, DC: Government Printing Office.

Table 2-14. Exports and Imports of Refractories: 1993–1999 (\$10⁶ 1998)

| Year | Exports | | | Imports | | | Apparent Consumption | | |
|------|---------|---------|-------|---------|---------|-------|----------------------|---------|---------|
| | Clay | Nonclay | Total | Clay | Nonclay | Total | Clay | Nonclay | Total |
| 1993 | 72.8 | 251.9 | 324.7 | 28.8 | 177.7 | 206.5 | 740.3 | 1,065.2 | 1,805.5 |
| 1994 | 62.1 | 262.9 | 325.5 | 26.4 | 183.7 | 210.1 | 843.3 | 992.8 | 1,836.1 |
| 1995 | 76.8 | 298.0 | 374.8 | 33.2 | 198.6 | 231.8 | 873.8 | 1,045.6 | 1,919.3 |
| 1996 | 71.7 | 314.7 | 386.4 | 27.0 | 211.1 | 238.2 | 856.9 | 1,077.4 | 1,934.3 |
| 1997 | 81.8 | 290.1 | 372.0 | 27.8 | 248.3 | 275.9 | 863.5 | 1,197.5 | 2,061.0 |
| 1998 | 59.6 | 278.9 | 338.6 | 30.9 | 225.1 | 256.0 | 942.0 | 1,113.3 | 2,055.3 |
| 1999 | 53.2 | 287.4 | 340.6 | 104.0 | 218.7 | 323.2 | 934.5 | 989.0 | 1,923.6 |

Source: U.S. Department of Commerce, Bureau of the Census. 1993–1999. *Current Industrial Reports: Refractories*. MA 32C. Available at <<http://www.census.gov/industry/ma32c97>>.

Table 2-15. Average Price for Refractory Products^a (\$/ton)

| Form | 1989 | | 1993 | | 1998 |
|--------------------|---------|------|---------|------|---------|
| | Current | 1998 | Current | 1998 | Current |
| Monolithics | 451 | 526 | 491 | 544 | 533 |
| Bricks and shapes | 709 | 826 | 782 | 866 | 910 |
| Other ^b | 394 | 459 | 442 | 490 | 497 |

^a Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics, 2001. <<http://146.142.4.24/cgi-bin/surveymost>>.

^b Other refractory forms consist of ceramic fibers and refractory raw materials that are supplied in lump or ground form used to manufacture refractories “in-house.”

Source: Freedonia Group. September 1999. “Refractories in the United States to 2003.” Profound WorldSearch <<http://www.profound.com>>

A recent study projects that shipments of U.S. refractory products will increase 2.5 percent annually to \$2.9 billion in 2003 (*Ceramic Industry*, 2000). In 1997, refractory products shipments increased 10.7 percent. The refractory industry typically parallels the steel industry, which is expected to maintain steady growth in the next few years (Bagsarian, 2001).

In recent years, consumption of domestically produced refractory products has declined somewhat, as a result of several compounding trends. First, the quality of refractory products has increased, resulting in longer life and fewer replacements. Thus, the tons of refractory products consumed per ton of steel produced has declined somewhat. In addition, imports of refractory products have increased approximately 57 percent from 1993 to 1999, so a smaller share of the refractory products consumed domestically are produced domestically.

SECTION 3

ENGINEERING COST ANALYSIS

Control measures implemented to comply with the MACT standard will result in higher production costs for affected refractory facilities. The engineering analysis computed estimates of these compliance costs (annual, capital, operating, testing, monitoring, reporting and record keeping) for each affected facility under baseline economic conditions. These estimates serve as key inputs to the economic model.¹ The following section presents a brief overview of emissions from refractory products manufacturing and the estimated costs refractory products manufacturers are projected to incur to comply with the rule. More detailed information is provided in EPA's Background Information Document (BID) (EPA, 2001a).

3.1 Overview of Emissions from Refractory Manufacturing

Refractory products manufacturing facilities are sources of several HAPs. The specific types and quantities of HAPs emitted from any particular facility are largely a function of the types of raw materials used and how those materials are processed. Resin-bonded refractory curing ovens and kilns can emit phenol, formaldehyde, methanol, and ethylene glycol, depending on the type of resin used. When used as binders or additives in the production of nonresin-bonded refractory shapes, ethylene glycol and methanol also are emitted from shape dryers and kilns. Pitch-bonded refractory heated pitch storage tanks, shape dryers, and kilns emit POM. The heated pitch storage tanks, shape preheaters, defumers, and coking ovens used to produce pitch-impregnated refractories also emit POM. Nearly all process units that are used to produce chromium refractory products emit chromium, and a small percentage of the chromium emitted from kilns that are used to fire chromium refractories is in the hexavalent form of chromium (Cr^{+6}). HF and HCl are emitted from kilns that are used to fire clay refractory products.

¹In the market model, the engineering cost inputs are expressed per unit of refractory product (\$/ton) and used to shift the refractory supply functions in the market model to predict the response in price and production levels. Details can be found in Section 4 and Appendix A.

Section 112 of the Clean Air Act lists 189 HAPs and defines major sources as those facilities that emit or have the potential to emit at least 10 tons per year of any single HAP or at least 25 tons per year of any combination of HAPs. Area sources are those with potential uncontrolled emissions of less than 10 tons per year of any HAPs and less than 25 tons per year of combined HAPs. Synthetic area sources are area sources that would be major sources if existing controls at those facilities were not in place. In other words, synthetic area sources are those sources whose uncontrolled HAP emissions exceed the major source thresholds of 10 tons per year of a single HAP or 25 tons per year of combined HAPs. Synthetic area sources are of particular significance because those facilities are included in the MACT floor analysis for existing sources, whereas “true” area sources are not included in the floor determinations and are not subject to the requirements of the rule.

Based on the HAP emission estimates within the refractory products manufacturing industry, six facilities emit at least 10 tons per year of a single HAP and two other facilities emit more than 8.5 tons/yr of a single HAP. In view of the uncertainties in emission estimation techniques, these two facilities also could be major sources. The Agency estimates that, of the 167 refractory products manufacturing facilities currently in operation in this source category, 152 are area sources, 8 are major sources, and 7 are synthetic area sources.

The Agency estimates that of the eight major sources three emit major amounts of HF emissions and HCl emissions resulting from clay calcining and/or clay refractory manufacturing and are not expected to be subject to the rule (because only new clay kilns, and not existing kilns, would be subject to substantive requirements of the rule for reducing HF and HCl). New kilns used to fire chromium refractories would similarly be subject only to new source MACT and would not be required to control existing sources for reducing chromium emissions from kilns.

Therefore, five of the eight existing major sources would have costs associated with compliance with the standard for organic HAPs. Costs for these facilities are shown in Table 3-1. Two of the five major sources that are subject to the rule would only incur costs of compliance associated with record keeping, reporting, and monitoring requirements, because these two plants are very well controlled now. EPA estimates that, in addition to the eight major sources, two facilities are major sources for POM emissions resulting from co-located graphite manufacturing operations. However, for the refractory products NESHAP, both of these plants are considered area sources because HAP emissions from the refractory products manufacturing operations at the

Table 3-1. Summary of Revised Annual Compliance Costs for Refractory Products Manufacturing NESHAP

| Plant ID | Initial Capital Cost (\$) | Control Costs | | | | | | | | | | Annual-ized Capital Cost (\$/yr) | Annual Overhead Cost (\$/yr) | Annual Taxes, Ins., Admin. Cost (\$/yr) | Annual Maintenance Material Cost (\$/yr) | Annual Energy Cost (\$/yr) | Annual Labor Cost (\$/yr) | Total Annualized Control Costs (\$/yr) | Annual-ized Monitoring Cost (\$/yr) | Annual-ized Record-keeping Cost (\$/yr) | Total Annualized Cost (\$/yr) |
|----------|---------------------------|----------------------------------|------------------------------|---|--|----------------------------|---------------------------|--|-------------------------------------|---|-------------------------------|----------------------------------|------------------------------|---|--|----------------------------|---------------------------|--|-------------------------------------|---|-------------------------------|
| | | Annual-ized Capital Cost (\$/yr) | Annual Overhead Cost (\$/yr) | Annual Taxes, Ins., Admin. Cost (\$/yr) | Annual Maintenance Material Cost (\$/yr) | Annual Energy Cost (\$/yr) | Annual Labor Cost (\$/yr) | Total Annualized Control Costs (\$/yr) | Annual-ized Monitoring Cost (\$/yr) | Annual-ized Record-keeping Cost (\$/yr) | Total Annualized Cost (\$/yr) | | | | | | | | | | |
| R005 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$900 | \$900 |
| R012 | \$1,368,200 | \$194,800 | \$48,300 | \$54,700 | \$31,900 | \$218,700 | \$48,600 | \$597,000 | \$8,000 | \$8,000 | \$648,700 | | | | | | | | | | |
| R027 | \$944,100 | \$134,400 | \$8,500 | \$37,800 | \$5,600 | \$71,700 | \$8,600 | \$266,600 | \$4,800 | \$8,000 | \$289,400 | | | | | | | | | | |
| R065 | \$383,400 | \$54,600 | \$12,400 | \$15,300 | \$8,200 | \$176,800 | \$12,500 | \$279,900 | \$1,600 | \$8,000 | \$291,500 | | | | | | | | | | |
| R111 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$900 | \$900 | | | | | | | | | | |
| R112 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$900 | \$900 | | | | | | | | | | |
| R128 | \$0 | \$0 | \$0 | \$0 | \$0 | \$48,000 | \$0 | \$48,000 | \$12,800 | \$8,000 | \$101,100 | | | | | | | | | | |
| R178 | \$794,100 | \$113,100 | \$19,900 | \$31,800 | \$13,100 | \$54,600 | \$20,000 | \$252,500 | \$4,800 | \$8,000 | \$277,600 | | | | | | | | | | |
| Total | \$3,489,800 | \$496,900 | \$89,100 | \$139,600 | \$58,800 | \$569,800 | \$89,700 | \$1,444,000 | \$32,000 | \$41,800 | \$1,610,100 | | | | | | | | | | |

two plants are negligible, and neither plant operates sources or equipment that would be subject to the refractory products NESHAP.

3.2 Compliance Cost Estimates

Sources of emissions at refractory manufacturing facilities that are covered by the NESHAP for refractory manufacturing are

- new kilns that fire chromium refractories and clay refractories and
- heated processes that emit organic HAPs at new and existing sources, including
 - curing ovens, drying ovens (shape dryers), and kilns used at refractory product manufacturing facilities that are major sources emitting organic HAPs from the affected sources, and
 - brick preheaters, pitch working tanks, defumers, and coking ovens used at pitch-impregnated refractory manufacturing facilities.

As noted above, HAPs that EPA has identified as being emitted from refractory manufacturing facilities include chromium, HF, HCl, phenol, POM, ethylene glycol, methanol, and formaldehyde.

The costs associated with improved emissions control are estimated based on what each plant may have to do to control organic HAP emissions. Controlled sources include thermal process units (i.e, dryers, curing ovens, kilns, coking ovens, defumers, and heated pitch storage tanks) that emit one or more organic HAPs. As shown in Table 3-1, the Agency estimates the nationwide costs of the rule are \$1.61 million, or approximately \$31.90 per ton of refractory product manufactured at facilities incurring compliance costs. EPA estimates that initial capital costs will total \$3.5 million. These capital costs, annualized over a period of 20 years at a 7 percent rate of interest, result in annualized capital costs of approximately \$497,000. The total annualized costs include these annualized capital costs, \$947,000 of annual overhead, administrative, and operating and maintenance costs for emissions controls, and \$166,000 of monitoring, recordkeeping, and reporting costs. Among the five facilities incurring costs, the total annualized costs range from \$101,000 to \$649,000 and average \$201,000.

3.2.1 Emission Control Costs

Emission control costs include the costs of purchasing and installing emission control capital equipment, and operating and maintenance costs including the costs of labor, materials, and energy to operate the controls, and any associated costs such as administrative costs, insurance, or taxes associated with the emission controls. Four facilities are projected to incur capital emissions control costs under the refractories NESHAP, ranging from \$383,400 to \$1.37 million. Because the cost of this capital equipment is a large lump-sum expenditure, companies typically finance the cost over a period of years. Thus, EPA estimates the annualized capital costs of the rule by annualizing the lump-sum capital costs over a period of 20 years at a 7 percent discount rate. The annualized capital costs range from \$54,600 to \$194,800. Among the annual emissions control costs, the highest costs are associated with incremental energy required to operate the controls. Energy control costs range from \$48,000 to \$218,700 per year and total \$569,800. Total annualized emission control costs for the refractories NESHAP range from \$48,000 to \$597,000 and total \$1.44 million, which is 90 percent of the total annualized costs of the rule. Of this total, \$947,000 represent annual operating and maintenance costs of the controls (59 percent of the rule's total costs), and \$496,900 represent the annualized cost of the control equipment (31 percent of the rule's total annualized costs).

3.2.2 Compliance Testing Costs

All affected sources must be tested for combustion efficiency by simultaneous testing using Methods 10 for carbon monoxide (CO), 3A for carbon dioxide (CO₂), and 25A for total hydrocarbons (THC), with one exception: plants that operate affected kilns that currently are uncontrolled and follow long curing or drying cycles would opt for the Method 18 test. Only one major source plant meets this criteria. Continuous sources, such as tunnel kilns, would be tested for three 1-hour test runs while periodic sources would be tested over three separate process cycles (up to 20 hours per cycle). The compliance test must be repeated every 5 years. Testing costs were annualized over a 5-year period using a 7 percent discount rate. Testing costs at the five refractory manufacturing facilities incurring costs range from \$2,000 per year to \$35,700 per year and total \$92,300 or 5.7 percent of the total annualized costs of the regulation.

3.2.3 Monitoring, Recordkeeping, and Reporting Costs

Monitoring costs include the cost of installing and operating a system to measure and record control device operating temperatures on a continuous basis. System components include a thermocouple and a data acquisition system. Annualized costs were computed assuming a data acquisition system life of 15 years, a thermocouple life of 2 years, and a 7 percent discount rate. Monitoring costs for facilities incurring costs range from \$1,600 to \$12,000 and total \$32,000 or 2 percent of the rule's total annualized costs. Annual reporting and recordkeeping costs were estimated using Standard Form 83 and were considered one-time costs annualized over a 5-year period at a 7 percent discount rate. Recordkeeping and reporting costs are estimated to range from \$900 to \$8,000 for facilities incurring costs. Overall, the \$41,800 recordkeeping and reporting costs represent 2.6 percent of the rule's total annualized costs.

3.2.4 Total Annualized Costs

Summing all categories of costs together, the five refractory manufacturing facilities are projected to incur total annualized costs ranging from \$101,100 to \$648,700. Total annualized costs for the rule are estimated to be \$1,610,100.

SECTION 4

ECONOMIC IMPACT ANALYSIS: METHODS AND RESULTS

The underlying objective of the EIA is to evaluate the effect of the proposed regulation on the welfare of affected stakeholders and society in general. Although the engineering cost analysis presented in Section 3 does represent an estimate of the respective plants' resources required to comply with the regulation under baseline economic conditions, the analysis does not account for the fact that the regulations may cause the economic conditions to change. For instance, producers may elect to discontinue production rather than comply, thereby reducing market supply. Moreover, the control costs may be passed along to other parties through various economic exchanges (such as price increases). The purpose of this section is to develop and apply an analytical structure for measuring and tracking these effects as they are distributed across the stakeholders tied together through economic linkages.

4.1 Markets Affected by the Proposed NESHAP

Refractory products are in fact fairly specialized, and each batch could be considered a unique product. For modeling the impacts, however, EPA aggregated the refractory products produced by manufacturers in the industry into broad markets. We considered two aggregation schemes: by type of input or material (clay and nonclay) or by form of output. While the *Census of Manufactures* divides refractories into clay and nonclay, we have concluded that the consumers of refractory products are more concerned about their form than their raw material. Therefore, EPA estimated impacts in three broad refractory product markets:

- bricks and shapes,
- monolithics (not directly affected by the NESHAP), and
- refractory ceramic fibers or RCF (not affected by the NESHAP).

These are the refractory products for which EPA's database provides information. For each facility in the industry, EPA has estimated quantities of each of these products manufactured on-site.

4.2 Conceptual Approach

The Agency developed a simple national competitive market model to estimate the economic impacts on society resulting from the proposed regulation. In these markets buyers and sellers exert no individual influence on market prices for refractory commodities potentially affected by the rule. Prices in these markets are set by the collective actions of producers and consumers, who take the market price as a given in making their production and consumption choices.

4.2.1 Producer Characterization

Many refractory plants produce multiple refractory products. Therefore, individual *product-line* supply decisions for existing producers were modeled in this analysis. These decisions were modeled as intermediate-run decisions, assuming that the plant size, equipment, and technologies are fixed. Given the existence of these fixed production factors, each product line was characterized by an upward-sloping supply function (see Figure 4-1). A profit-maximizing firm will select its output level according to this schedule as long as the market price is sufficiently high to cover average variable costs (i.e., greater than C_0 in Figure 4-1). Thus, in the short run, a profit-maximizing firm will not pass up an opportunity to recover even part of its fixed investment in plant and equipment. These individual supply decisions were aggregated (i.e., horizontally summed) to develop a market supply curve for each refractory product. The majority of the industry is not affected directly; however, they are affected indirectly by the decrease in the quantity of refractory products in the industry and the resulting increase in price. Similarly, foreign refractory producers will respond to the higher refractory prices in the U.S. by supplying more to the U.S. market.

4.2.2 Consumer Characterization

Demand for refractory products comes mainly from the iron and steel industry, cement industry, and nonferrous metals industry, although smaller shares are sold for use in glass manufacturing and oil refining. The U.S. International Trade Commission (1994) estimates that over 50 percent of refractories are used in the iron and steel industry; DHAN (1999) estimated this share to be 75 percent. There are no direct substitutes for refractory products. Nevertheless, over time, consumers of refractory products have reduced the amount of refractory products consumed. Over the past 20 years, the iron and steel industry has restructured, closing inefficient facilities and modernizing remaining plants. Newer steelmaking technologies significantly reduced the amount of refractories used per ton of steel. Given data limitations, each commodity market will be modeled

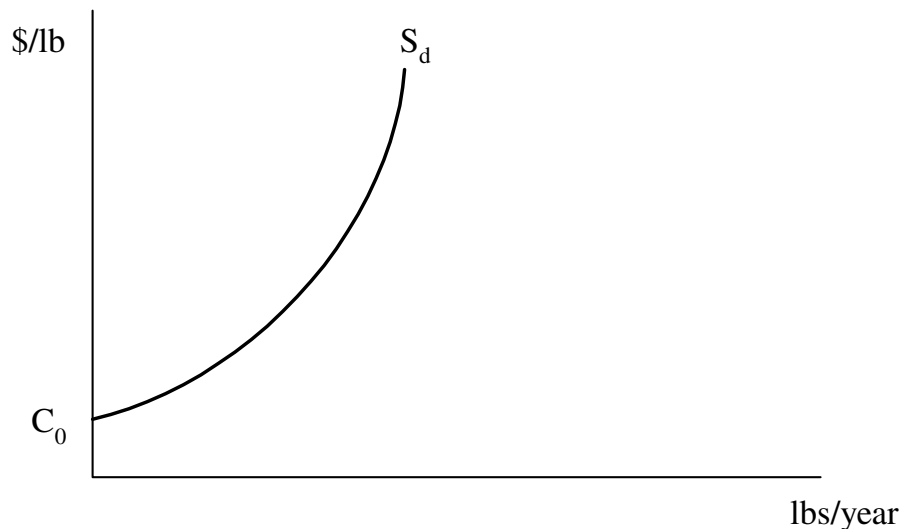


Figure 4-1. Supply Curve for a Representative Directly Affected Facility

as having a single aggregate consumer with a downward-sloping market demand curve (see Figure 4-2).

4.2.3 Foreign Trade

While the proposed NESHAP will directly affect domestic facilities that produce refractory products, the rule can also have indirect foreign trade implications. The consequent change in relative prices of domestic versus foreign refractory products has two impacts on foreign trade. Foreign imports become more attractive to U.S. refractory consumers and U.S. exports become less attractive to foreign refractory consumers. On the import side, the demand for imported refractories could increase if they become inexpensive relative to domestic refractories that are affected by the regulation. We will assume that foreign firms can meet this spillover demand by using excess capacity in their existing plants. On the export side, foreign demand for refractories produced in the United States may decrease if they become relatively more expensive because of the regulation. Finally, domestic facilities could relocate to foreign countries with laxer environmental regulations if domestic production costs increase. However, given the relatively small size of the expected compliance costs it is unlikely that the proposed regulations will trigger

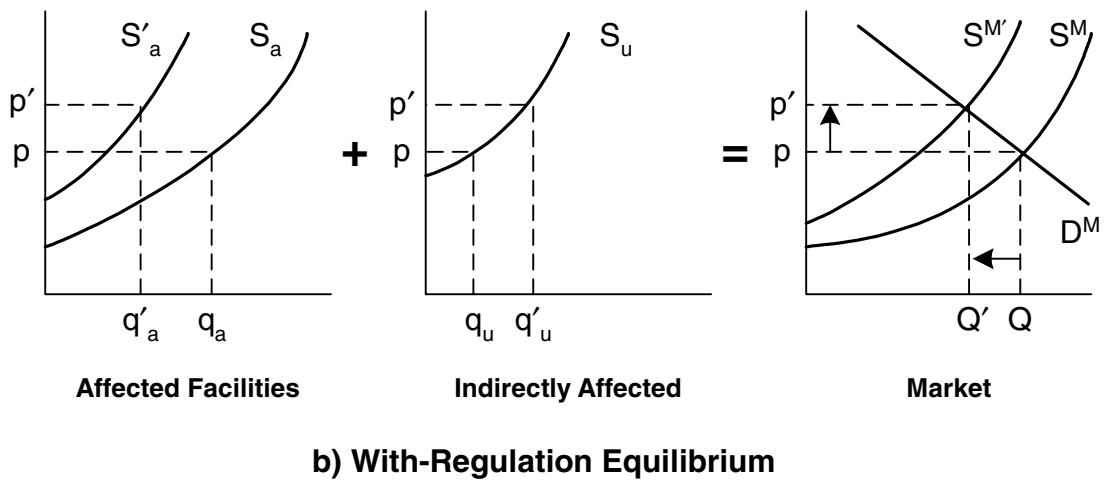
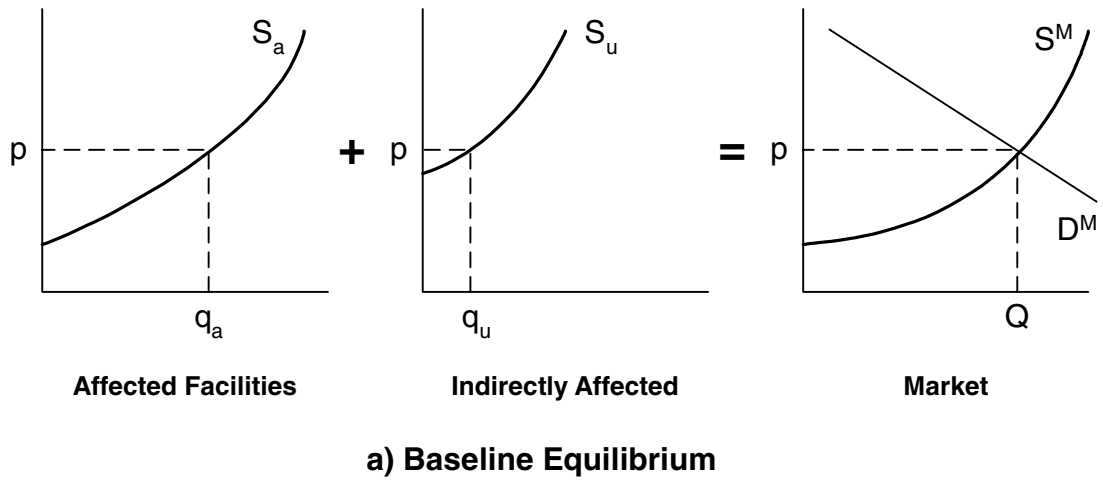


Figure 4-2. Market Equilibrium without and with Regulation

industrial flight at least in the short run. This assumption is consistent with empirical studies in the literature that have found little evidence of environmental regulations affecting industry location decisions (Levinson, 1996). RTI will use available data to estimate the magnitude of these impacts as described below.

4.2.4 Baseline and With-Regulation Equilibrium

A graphical representation of the competitive model of price formation, as shown in Figure 4-2(a), posits that market prices and quantities are determined by the intersection of the market supply and demand curves. Under the baseline scenario, a market price and quantity (p, Q) are determined by the downward-sloping market demand curve (D) and the upward-sloping market supply curve (S) that reflects the sum of the individual supply curves of domestic plants that produce a given refractory product.

With the regulation, the costs of production increase for affected suppliers. These additional costs include a variable component consisting of the operating and maintenance costs and a fixed component that does not vary with output (i.e., expenditures for control-related capital equipment to comply with the regulatory alternative). The imposition of these regulatory control costs is represented as an upward shift in the supply curve for each directly affected product line. As a result of the upward shift in these individual supply curves, the market supply curve for refractory products will shift upward as shown in Figure 4-2(b) to reflect the increased costs of production at affected plants.

In baseline without the proposed standards, the industry produces total output at quantity, Q , at price, p , with directly affected facilities producing the amount q_d and indirectly affected facilities accounting for Q minus q_d , or q_i . With the regulation, the market price increases from p to p' , and market output (as determined from the market demand curve, D) declines from Q to Q' . This reduction in market output is the net result of reductions at directly affected facilities and increases at indirectly affected facilities, including both foreign and domestic refractory product manufacturing plants not incurring costs.

4.3 Economic Impact Results

To develop quantitative estimates of these impacts, EPA developed a computer model using the conceptual approach described above.¹ Using this model, EPA characterized supply and demand of three refractory commodities—bricks and shapes, monolithics, and refractory ceramic fiber (RCFs)—for the baseline year, 1998; introduced a policy “shock” into the model by using control cost-induced shifts in the supply functions of affected producers; and used a solution

¹Appendix A includes a description of the baseline data set, model equations, and solution algorithm.

algorithm to determine a new with-regulation equilibrium in each refractory market. We report the market, industry, and societal impacts projected by the model below.

4.3.1 Market-Level Impacts

The price of refractory products is expected to increase slightly and production and consumption decline from 1997 baseline levels. As shown in Table 4-1, the regulation is projected to increase the price of refractory products by less than 0.1 percent, or an \$0.82 per short ton increase over the 1998 price of \$910 per ton. Domestic production is projected to decline by approximately 0.03 percent, or a decrease of 559 short tons from the 1998 production of 2.1 million tons. This is partially offset by an increase in imports of 329 tons.

Table 4-1. Market-Level Impacts: 1998

| | Baseline | With Regulation | Change Absolute | Relative |
|--------------------------|-----------------|----------------------------|----------------------------|-----------------|
| Bricks and Shapes | | | | |
| Price (\$/ton) | \$910.00 | \$910.82 | \$0.82 | 0.09% |
| Quantity (short tons) | 2,360,863 | 2,360,634 | -229 | -0.01% |
| Domestic | 2,177,356 | 2,176,798 | -559 | -0.03% |
| Imports | 183,507 | 183,836 | 329 | 0.18% |
| Monolithics | | | | |
| Price (\$/ton) | \$533.00 | \$533.06 | \$0.06 | 0.01% |
| Quantity (short tons) | 959,656 | 959,645 | -11 | 0.00% |
| RCF | | | | |
| Price (\$/ton) | \$497.00 | \$497.00 | \$0.00 | 0.00% |
| Quantity (short tons) | 34,490 | 34,490 | 0 | 0.00% |

4.3.2 Industry-Level Impacts

Industry revenue, costs, and profitability change as prices and production levels adjust to increased production costs. As shown in Table 4-2, the economic model projects that profits for refractory producers will increase by \$0.5 million, or 0.43 percent. Although most would think that

Table 4-2. Industry-Level Impacts: 1998

| | Baseline | With Regulation | Change | |
|--|-----------|--------------------|----------|----------|
| | | | Absolute | Relative |
| Total revenue (\$10 ⁶ /yr) | \$2,510.0 | \$2,511.4 | \$1.3 | 0.05% |
| Total costs (\$10 ⁶ /yr) | \$2,396.2 | \$2,397.1 | \$0.8 | 0.03% |
| Control | \$0 | \$1.3 | \$1.3 | NA |
| Production | \$2,396.2 | \$2,395.8 | -\$0.4 | -0.02% |
| Pre-tax earnings (\$10 ⁶ /yr) | \$113.8 | \$114.3 | \$0.5 | 0.43% |
| Facilities (#) | 162 | 161 | -1 | -0.62% |
| Employees (FTEs ^a) | 13,840 | 13,833 | -7 | -0.05% |

^a FTEs = full-time equivalent employees.

profits would decrease as a result of increasing costs of production, the three effects below describe why profits increase after the rule:

- Net increase in revenue (\$1.3 million): Industry-wide refractory product revenue increases because 157 of 162 refractory manufacturing facilities with production data experience increased prices with no increase or very small increases in costs; thus, their production and revenue are projected to increase. Their increased profits exceed the reduced profits of the five plants incurring significant emissions control costs.
- Net decrease in production costs (\$0.4 million): A net reduction in refractory production costs occurs as output declines at facilities incurring compliance costs.
- Increase in control costs (\$1.3 million): The costs of production increase as a result of regulatory controls.

Additional distributional impacts of the rule within each producer segment are not necessarily apparent from the reported decline or increase in their aggregate operating profits. The regulation creates both gainers and losers within each industry segment based on the distribution of compliance costs across facilities. As shown in Table 4-3, facilities incurring emissions control costs (i.e., five plants, or 3 percent) are projected to become less profitable with the regulation with

Table 4-3. Distributional Impacts Across Facilities: 1998

| | Operating Profit | | |
|--|-------------------|-------------------|-------------|
| | Loss ^a | Gain or No Change | Total |
| Facilities (#) | 5 | 157 | 162 |
| Compliance costs | | | |
| Total (\$/yr) | \$1,608,300 | \$2,700 | \$1,611,000 |
| Average (\$/short ton) | \$23.13 | \$0.00 | \$0.51 |
| Change in pre-tax earnings (\$10 ⁶ /yr) | -\$1.30 | \$1.79 | \$0.49 |

^aThe loss column includes one projected facility closure.

a total loss of \$1.3 million. However, 157 facilities are projected to experience either a total profit gain, because they will receive higher refractory prices without additional control costs. Foreign producers will also experience increased revenues due to the higher refractory prices and will claim a slightly larger share of the bricks and shapes market.

4.3.2.1 Facility Closures and Changes in Employment

EPA estimates that one facility is likely to prematurely close as a result of the regulation. However, this facility has options to reduce the emissions or change the processes such that they would no longer be classified as a major source and not incur any compliance costs. The cost to this facility would then be the amount necessary to convert to nonmajor source status. Because we do not know how this facility will respond, our model imposes the MACT regulation costs on this facility and predicts a closure because the cost of production exceeds revenue. This facility is estimated to employ fewer than ten employees at baseline; other plants incurring costs may reduce employment slightly as their output declines. However, facilities not incurring compliance costs may increase their employment slightly in response to higher refractory prices. On balance, EPA does not expect industry employment to change significantly.

4.3.3 Social Cost

The social impact of a regulatory action is traditionally measured by the change in economic welfare that it generates. The social costs of the proposed rule will be distributed across producers

of refractory products and their customers. Consumers of refractory products experience welfare impacts due to changes in market prices and consumption levels associated with the rule. Producers experience welfare impacts resulting from changes in profits corresponding with the changes in production levels and market prices. However, it is important to emphasize that this measure does not include benefits that occur outside the market, that is, the value of reduced levels of air pollution with the regulation.

The national compliance cost estimates are often used as an approximation of the social cost of the rule. The engineering analysis estimated annual costs of \$1.66 million. In cases where the engineering costs of compliance are used to estimate social cost, the burden of the regulation is measured as falling solely on the affected facilities, which experience a profit loss exactly equal to these cost estimates. Thus, the entire loss is a change in producer surplus with no change (by assumption) in consumer surplus, because no change in market price is estimated. This is typically referred to as a “full-cost absorption” scenario in which all factors of production are assumed to be fixed and firms are unable to adjust their output levels when faced with additional costs.

In contrast, the economic analysis conducted by the Agency accounts for behavioral responses by producers and consumers to the regulation, as affected producers shift costs to other economic agents. This approach results in a social cost estimate that may differ from the engineering compliance cost estimate and also provides insights on how the regulatory burden is distributed across stakeholders. The computation of social costs is discussed in detail in Appendix B. As shown in Table 4-4, the economic model estimates the total social cost of the rule to be \$1.35 million. Although society reallocates resources as a result of the increased cost of refractory production, only a relatively small change in social welfare occurs. Users of refractory products (i.e., consumers such as the steel industry) experience a decline in welfare of \$1.99 million, because of increased prices and decreased consumption. Industry-wide, refractory producers experience a net gain of \$0.64 million. This net gain includes welfare changes experienced by facilities incurring compliance costs (which experience increased costs and decreased output and profit, along with an increase in price) and welfare changes experienced by facilities—both foreign and domestic—that do not incur compliance costs (which receive higher prices for their commodities and respond by producing more). It also reflects the projected premature closure of one refractory manufacturing facility. Overall, however, the impacts on both refractory manufacturers and their customers are projected to be relatively small.

Table 4-4. Distribution of Social Costs: 1998

| | Value (\$10 ⁶ /yr) |
|-------------------|-------------------------------|
| Consumer surplus | -\$1.99 |
| Bricks and shapes | -\$1.93 |
| Monolithics | -\$0.06 |
| RCF | \$0.00 |
| Producer surplus | \$0.64 |
| Domestic | \$0.49 |
| Foreign | \$0.15 |
| Total social cost | -\$1.35 |

4.3.4 Full-Cost-Absorption Scenario

EPA's analysis of impacts on refractory manufacturers assumed that refractory manufacturers, responding to costs of compliance, would attempt to shift some of the cost to their customers by raising the price of their products. Refractory consumers would reduce the quantity demanded of refractory products, thus resulting in shifts in market prices and quantities, and leading to changes in output, revenues, costs, and profits at both directly affected and indirectly affected refractory producers.

Because of evidence of oligopsony power and lower foreign prices about which EPA has heard from industry, refractory producers may be unable to increase their prices in response to the increased costs associated with compliance. To assess the impacts on the industry if this is true, EPA has analyzed the impacts of the NESHAP using a full-cost-absorption scenario.

The full-cost-absorption scenario is a simplified analysis that uses the following assumptions: costs are imposed on facilities and are added to baseline production costs at directly affected facilities. Neither prices nor quantities are permitted to adjust in response to the higher costs.

Thus, the only impact of the higher costs is to reduce the profits of directly affected facilities. Facilities whose costs exceed their baseline profits become unprofitable and are projected to close.

When EPA implemented the full-cost-absorption scenario, a single facility (the same one projected to close in the market analysis) is projected to become unprofitable and close. Other facilities are projected to continue producing the same quantity of refractory products as they do under baseline conditions. Facilities incurring compliance costs are projected to experience profit reductions equal to the compliance costs they incur. Facilities not incurring compliance costs are unaffected.

Thus, the full-cost-absorption scenario projects results similar to the market analysis. EPA believes that the market analysis, which allows market price and quantity to adjust in response to the costs of complying with the NESHAP, is a more realistic assessment of actual impacts, including a more accurate estimate of the distributional impacts of the regulation.

SECTION 5

SMALL BUSINESS IMPACTS

Environmental regulations like this rule potentially affect all businesses, large and small, but small businesses may have special problems complying with such regulations. The Regulatory Flexibility Act (RFA) of 1980 as amended in 1996 by the Small Business Regulatory Enforcement Fairness Act (SBREFA) generally requires an agency to prepare a regulatory flexibility analysis of a rule unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small businesses, small governmental jurisdictions, and small organizations. This section examines the proposed rule's impact on these entities.

5.1 Identify Small Entities

For purposes of assessing the impacts of the proposed rule on small entities, a small entity is defined as: (1) a small business according to Small Business Administration (SBA) size standards for NAICS code 327124 (Clay Refractories) of 500 or fewer employees or NAICS code 327125 (Nonclay refractories) of 750 or fewer employees;¹ (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field.

The Agency collected data on facility and company employment from the industry; additional data were collected from publicly available sources such as financial databases. Based on this employment data, EPA determined that 58 small entities within this source category would be subject to this proposed rule. Of the 80 companies owning refractory manufacturing facilities in the EPA database, only 17 have company-level employment data showing that they have more than

¹For purposes of this analysis, small businesses were defined as having 750 or fewer employees. Some of the companies in the refractory industry produce both clay and nonclay refractories, which does not allow us to assign companies unambiguously to a single NAICS code. For this reason, we selected the higher NAICS criterion, 750 employees, as the small business criterion for all companies. Note that this conservative criterion may overstate the total number of small companies.

750 employees. These are classified as large companies for purposes of this analysis. The remaining 58 companies are classified as small entities.

5.2 Economic Analysis

The Agency conducted a screening analysis to assess the impacts of the proposed rule on small businesses and to compare the impacts on small businesses with impacts on large businesses. These results are shown in Table 5-1. Only one of the estimated 58 small businesses in the refractory manufacturing industry is projected to incur costs to comply with the regulation. By contrast, the seven large companies projected to incur compliance costs experience costs averaging \$188,400 per company. Even for the large businesses incurring costs, however, none experience costs exceeding 1 percent of baseline sales.

Table 5-1. Summary Statistics for SBREFA Screening Analysis: 1998

| | Small | | Large | | Total | |
|---|-----------|-------|-------------|-------|-------------|-------|
| Total number of companies | 58 | | 22 | | 80 | |
| Total annual compliance costs (TACC) (\$/year) | \$293,300 | | \$1,317,700 | | \$1,611,000 | |
| Average TACC per company (\$/year) ^a | NR | | \$188,400 | | \$201,300 | |
| | Number | Share | Number | Share | Number | Share |
| Companies with sales data | 33 | 100% | 17 | 100% | 50 | 100% |
| Compliance costs <1% of sales | 33 | 100% | 17 | 100% | 50 | 100% |
| Compliance costs 1% to 3% of sales | 0 | 0% | 0 | 0% | 0 | 0% |
| Compliance costs are >3% of sales | 0 | 0% | 0 | 0% | 0 | 0% |
| Compliance cost-to-sales ratios (CSRs) | | | | | | |
| Mean | 0.012% | | 0.008% | | 0.010% | |
| Median | 0.000% | | 0.000% | | 0.000% | |
| Maximum | 0.362% | | 0.066% | | 0.362% | |
| Minimum | 0.000% | | 0.000% | | 0.000% | |

^aAverage over companies incurring compliance costs.

NR = not reported to avoid revealing confidential data.

The Agency analyzed the economic impacts on small businesses under with-regulation conditions expected to result from implementing the proposed rule. This approach examines small

business impacts in light of the expected behavioral responses of producers and consumers to the regulation. As shown in Table 5-2, overall revenue and operating profits for facilities owned by small businesses are projected to increase under the recommended alternative. Only one small business incurs compliance costs. In response to the projected increase in market price for refractory products, most facilities owned by small businesses are projected to increase their output somewhat. As a result, they experience increased production costs but also increased revenues, profits, and employment.

Table 5-2. Small Business Impacts: 1998

| | Baseline | With Regulation | Change Absolute | Relative |
|--|-----------------|----------------------------|----------------------------|-----------------|
| Total revenue (\$10 ⁶ /yr) | \$506.6 | \$507.1 | \$0.4 | 0.09% |
| Total costs (\$10 ⁶ /yr) | \$489.0 | \$489.4 | \$0.4 | 0.08% |
| Control | \$0.0 | \$0.3 | \$0.3 | NA |
| Production | \$489.0 | \$489.1 | \$0.1 | 0.02% |
| Pre-tax earnings (\$10 ⁶ /yr) | \$17.6 | \$17.7 | \$0.0 | 0.19% |
| Facilities (#) | 76 | 76 | 0 | 0.00% |
| Employees (FTEs ^a) | 3,455 | 3,457 | 2 | 0.05% |

^a FTEs = full-time equivalent employees.

5.3 Assessment

The proposed refractories NESHAP is only expected to result in increased costs for one small business. Because the price of refractory products is expected to increase, most small companies are projected to increase their production, revenues, production costs, and profits. Overall, they are expected to benefit economically from the proposed rule. For the one small business incurring costs due to the proposed NESHAP, estimated compliance costs represent only 0.37 percent of baseline sales. Thus the rule is not expected to result in significant adverse economic impacts to any small business.

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APPENDIX A

OVERVIEW OF REFRACTORIES MARKET MODEL

To develop estimates of the economic impacts on society resulting from the proposed regulation, the Agency developed a computational model using a framework that is consistent with economic analyses performed for other rules. This approach employs standard microeconomic concepts to model behavioral responses expected to occur with the regulation. This appendix describes the spreadsheet model in detail and discusses how the Agency

- characterized the supply and demand of three refractory commodities—bricks and shapes, monolithics, and refractory ceramic fiber (RCFs);
- introduced a policy “shock” into the model by using control cost-induced shifts in the supply functions of affected producers; and
- used a solution algorithm to determine a new with-regulation equilibrium in each refractory market.

A.1 Baseline Data Set

Much of the data used in modeling the refractory industry comes from the EPA Refractory Industry Database, which contains confidential survey responses from potentially affected facilities. Among the critical data included in this database are product-specific output. Table A-1 lists additional plant and company data elements and their sources. Table A-2 shows prices of refractory products obtained from Freedonia Group. Although “other” refractory forms includes not only RCF but refractories that are shipped in bulk, EPA used this price for RCF.

A.2 Supply and Demand Elasticities

Unfortunately, empirical estimates of demand or supply elasticities for roofing products are limited. The option of estimating a system of demand and supply equations using three-stage least squares (3SLS) was not feasible because of limitations of time-series data. Although these

Table A-1. Types and Sources of Refractory and Processing Facility Data

| Data Category | Data Element | Data Source |
|----------------------|--|----------------------------------|
| Plant data | Plant name | EPA Refractory Industry Database |
| | Plant location | EPA Refractory Industry Database |
| | Plant ownership | EPA Refractory Industry Database |
| | Types of refractory products produced | EPA Refractory Industry Database |
| | Employment | EPA Estimate |
| | Quantity produced of each refractory product | EPA Refractory Industry Database |
| Company data | Company name | Ward's Business Directory |
| | Company sales | Ward's Business Directory |
| | Employment | Ward's Business Directory |
| Market data | Prices | Freedonia Group |

Sources: Freedonia Group. September 1999. "Refractories in the United States to 2003." Profound WorldSearch <<http://www.profound.com>>. Information Access Co. 2000. Ward's Business Directory. Belmont, CA
U.S. Environmental Protection Agency (EPA). 2001b. Refractory Industry Database.

limitations prevent estimation of these parameters, knowledge about the factors influencing the elasticity of derived demand makes it possible to develop informed assumptions about producer and consumer responses to price changes. Economic theory states that the elasticity of the derived demand for an input is a function of the following (Hicks, 1961; Hicks, 1966; and Allen, 1938):

- demand elasticity for the final good it will be used to produce,
- the cost share of the input in total production cost,
- the elasticity of substitution between this input and other inputs in production, and
- the elasticity of supply of other inputs.

Using Hicks' formula,

Table A-2. Refractory Products Pricing (\$/ton)

| Form | 1989\$ | 1998\$ | 1993\$ | 1998\$ | 1998\$ |
|--------------------|--------|--------|--------|--------|--------|
| Monolithics | 451 | 526 | 491 | 544 | 533 |
| Bricks and Shapes | 709 | 826 | 782 | 866 | 910 |
| Other ^a | 394 | 459 | 442 | 490 | 497 |

^a Other refractory forms consist of ceramic fibers and refractory raw materials that are supplied in lump or ground form used to manufacture refractories “in-house.”

Note: Prices were inflated using the producer price index for stone, clay, glass and concrete products available through the Bureau of Labor Statistics at <<http://146.142.4.24/cgi-bin/srgate>>.

Source: Freedonia Group. September 1999. “Refractories in the United States to 2003.” Profound WorldSearch <<http://www.profound.com>>.

$$\eta_i = \frac{[s(n+e) + Ke(n-s)]}{[n+e - K(n-s)]} \quad (\text{A.1})$$

where

η_i = elasticity of demand for the refractory product i ,

s = elasticity of substitution between refractory product i and all other inputs to steel production,

n = elasticity of demand for final product (steel products),

e = elasticity of supply of other inputs, and

K = cost share of refractory product i in total production cost.

In the appendix to *The Theory of Wages*, Hicks (1966) shows that, if $n > s$, the demand for the input is less elastic the smaller its cost share. If the data were available, this formula could be used to actually compute the elasticity of demand for each refractory product. The final products for which the refractory is an input include iron and steel products, other nonferrous metal products, and cement. The iron and steel industry dominates the demand for refractory products,

perhaps constituting as much as 75 percent of total refractory consumption. For this reason, EPA concentrated on the elasticity of demand for refractories in steelmaking. For the analysis of the Integrated Iron and Steel NESHAP, the Agency estimated the elasticity of demand for iron and steel products to be -0.59. Values in the literature have been in the same range, both for ferrous (-0.7) and nonferrous (-0.6) metals (Slade, 1996). Lacking estimates of other elasticities of final demand and of the other parameters in the formula makes direct computation of the elasticity of demand, η , impossible. In spite of this, the formula is useful because it identifies factors that influence the magnitude of the elasticity of derived demand. Knowledge of the general magnitude of those factors makes it possible to make an educated assumption about the magnitude of η .

The elasticity of substitution, s , between refractory products and other inputs is likely to be very low but nonzero. While there are no substitutes for refractories in the short run, over time, capital equipment has been substituted for refractories as technology has evolved requiring less use of refractories per ton of steel. We thus expect that $n > s$. This implies that the magnitude of η is proportional to the magnitude of K , the cost share of refractories in overall building construction. Based on the benchmark input-output accounts for the United States, stone and clay products (including refractories) are 1.5 percent of primary iron and steel manufacturing and 0.02 percent of primary nonferrous metals manufacturing (Lawson, 1997).

Given that the cost share of stone and clay products in the total production cost of ferrous and nonferrous primary metal manufacturing is small, the elasticity of demand for one of the final products (steel mill products) is relatively low, and ease of substitution between inputs very limited, the elasticity of demand for refractory products would be inelastic (i.e., less than 1 in absolute value). In fact, we suspect it may be substantially lower. Assuming the elasticity of supply of other inputs is 1, and the elasticity of substitution between refractory and other inputs is 0.1, the elasticity of demand for refractories would be approximately 0.1 in absolute value.

A.3 Operational Model

The Agency developed an operational model of the refractories industry using spreadsheet software. This model characterizes market supply and demand, allows the analyst to introduce a policy “shock” into the model by using control cost-induced shifts in the supply functions of affected producers, and uses a solution algorithm to determine a new with-regulation equilibrium for each refractory market. This section describes the computer model in detail.

A.3.1 Market Supply

Domestic supply for product i can be expressed as

$$Q^{S^i} = \sum_{j=1}^n q_{(j)}^{S^i} \quad (A.2)$$

where

$q_{(j)}^{S^i}$ = product i supply from domestic plant (j) and

n = the number of domestic suppliers producing commodity i.

A.3.1.1 Product Line Supply

EPA used a simple Cobb Douglas (CD) supply function for each facility product line expressed as follows:

$$q_{(j)}^{S_i} = A_i \cdot (P_i)^{\epsilon^{S_i}} \quad (A.3)$$

where

$q_{(j)}^{S_i}$ = the supply of product i for domestic plant (j),

A_i = a parameter that calibrates the supply equation to replicate the estimated 1998 level of production,

P_i = the 1998 market price for product i, and

ϵ^{S_i} = the domestic supply elasticity.

Regulatory Induced Shifts in the Supply Function (c_j). The upward shift in the supply function (c_j) is calculated by taking the total annual compliance cost estimate and dividing it by

baseline output. Computing the supply shift in this manner treats the compliance costs as the conceptual equivalent of a unit tax on output.

$$q_{(j)}^{S_i} = A_i \cdot (P_i - c_j)^{S_i} \quad (\text{A.3})$$

Plant Closure Analysis. One of the most sensitive issues to consider in the EIA is the possibility that the regulation may induce a producer to shut down operations rather than comply with the regulation. The data (i.e., direct observations of plant-level costs and profits) necessary to make definitive projections of these impacts are unavailable from the survey data. Therefore, EPA developed a crude method of identifying plant closure decisions using firm-specific or broad industry measures of profitability as described below.

The plant closure criterion used for this analysis is defined as follows:

$$\pi_j = TR_j - TC_j \leq 0 \quad (\text{A.4})$$

where total revenue (TR_j) is the sum of the product revenue from plant j 's product lines, and total cost (TC_j) is the sum of the plant's total variable production costs, total avoidable fixed production costs, and total control costs. The conceptually correct view would assume the plant also has some positive liquidation value or opportunity value in an alternative use that is not captured in the TC elements used to compute π_j . However, no data are available to estimate these opportunity costs. Therefore, the Agency has assumed they are exactly offset by the costs of closing a plant (i.e., equal to zero).

Given the estimated 1998 values of revenue and variable production costs implied by the calibrated product line supply functions, the Agency developed an estimate of the total avoidable fixed costs so that the profit ratio for each plant exactly matches either the parent company's profit margin or an industry profit ratio reported by the U.S. Internal Revenue Service (Contos and Legal, 2000).

A.3.2 Market Demand

Domestic demand is expressed as follows:

$$q^{D_i} = B_i \cdot P_i^{\eta^{D_i}} \quad (A.5)$$

where

q^{D_i} = domestic demand for product i ,

B_i = a parameter that calibrates the demand equation to replicate the 1998 level of domestic demand,

P_i = the 1998 market price for product i , and

η^{D_i} = the domestic demand elasticity for product i .

A.3.3 With-Regulation Market Equilibrium Determination

Producer responses and market adjustments can be conceptualized as an interactive feedback process. Plants facing increased production costs due to compliance are willing to supply smaller quantities at the baseline price. This reduction in market supply leads to an increase in the market price that all producers and consumers face, which leads to further responses by producers and consumers and thus new market prices, and so on. The new with-regulation equilibrium is the result of a series of iterations in which price is adjusted and producers and consumers respond, until a set of stable market prices arises where total market supply equals market demand (i.e., $Q_s = Q_D$) in each market. Market price adjustment takes place based on a price revision rule that adjusts price upward (downward) by a given percentage in response to excess demand (excess supply).

The algorithm for determining with-regulation equilibria can be summarized by five recursive steps:

1. Impose the control costs on all affected plants, thereby affecting their supply decisions.
2. Recalculate the market supply in each product market.
3. Determine the new prices via the price revision rule for each product market.

4. Recalculate the supply functions with the new price, resulting in a new market supply of each product. Compute market demand at the new prices.
5. Go to Step 3, resulting in a new price. Repeat until equilibrium conditions are satisfied (i.e., the ratio of supply to demand is arbitrarily close to one).

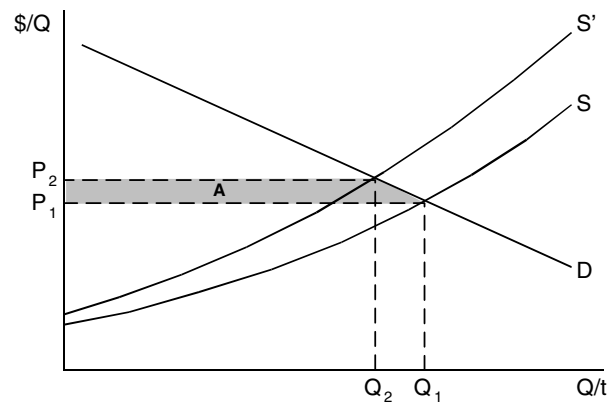
APPENDIX B

ECONOMIC WELFARE IMPACTS ON REFRACTORY INDUSTRY

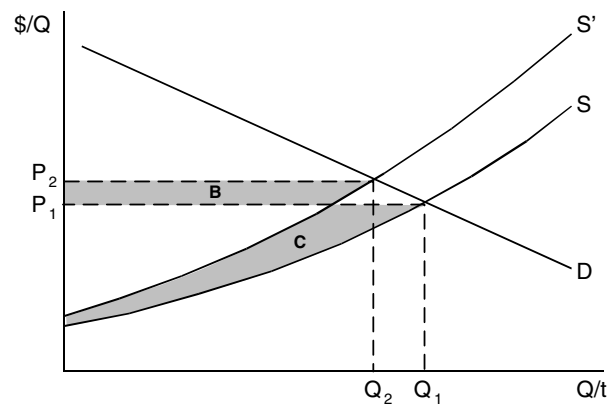
The economic welfare implications of the market price and output changes with the regulation can be examined using two different strategies, each giving a somewhat different insight but the same implications: changes in the net benefits of consumers and producers based on the price changes and changes in the total benefits and costs of these products based on the quantity changes. This analysis focuses on the first measure—the changes in the net benefits of consumers and producers. Figure B-1 depicts the change in economic welfare by first measuring the change in consumer surplus and then the change in producer surplus. In essence, the demand and supply curves previously used as predictive devices are now being used as a valuation tool.

This method of estimating the change in economic welfare with the regulation divides society into consumers and producers. In a market environment, consumers and producers of the good or service derive welfare from a market transaction. The difference between the maximum price consumers are willing to pay for a good and the price they actually pay is referred to as “consumer surplus.” Consumer surplus is measured as the area under the demand curve and above the price of the product. Similarly, the difference between the minimum price producers are willing to accept for a good and the price they actually receive is referred to as “producer surplus” or profits. Producer surplus is measured as the area above the supply curve and below the price of the product. These areas can be thought of as consumers’ net benefits of consumption and producers’ net benefits of production, respectively.

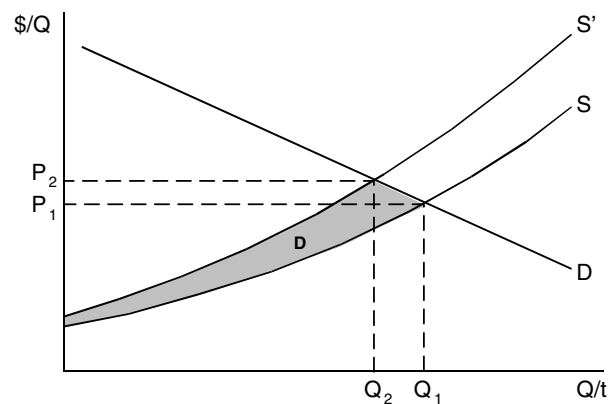
In Figure B-1, baseline equilibrium occurs at the intersection of the demand curve, D , and supply curve, S . Price is P_1 with quantity Q_1 . The increased cost of production with the regulation will cause the market supply curve to shift upward to S' . The new equilibrium price of the product is P_2 . With a higher price for the product, there is less consumer welfare, all else being unchanged as real incomes are reduced. In Figure B-1(a), area A represents the dollar value of the annual net loss in consumers’ benefits with the increased price. The



(a) Change in Consumer Surplus with Regulation



(b) Change in Producer Surplus with Regulation



(c) Net Change in Economic Welfare with Regulation

Figure B-1. Economic Welfare Changes with Regulation: Consumer and Producer Surplus

rectangular portion represents the loss in consumer surplus on the quantity still consumed, Q_2 , while the triangular area represents the foregone surplus resulting from the reduced quantity consumed, $Q_1 - Q_2$.

In addition to the changes in consumer welfare, producer welfare also changes with the regulation. With the increase in market price, producers receive higher revenues on the quantity still purchased, Q_2 . In Figure B-1(b), area B represents the increase in revenues due to this increase in price. The difference in the area under the supply curve up to the original market price, area C, measures the loss in producer surplus, which includes the loss associated with the quantity no longer produced. The net change in producer welfare is represented by area B–C.

The change in economic welfare attributable to the compliance costs of the regulation is the sum of consumer and producer surplus changes, that is, $-(A) + (B - C)$. Figure B-1(c) shows the net (negative) change in economic welfare associated with the regulation as area D. However, this analysis does not include the benefits that occur outside the market (i.e., the value of the reduced levels of air pollution with the regulation). Including this benefit may reduce the net cost of the regulation or even make it positive.

TECHNICAL REPORT DATA*(Please read Instructions on reverse before completing)*

| | | |
|---|---|---------------------------------|
| 1. REPORT NO. EPA-452/R-01-017 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE Economic Impact Analysis of the Refractory Product Manufacturing NESHAP | 5. REPORT DATE December 2001 | 6. PERFORMING ORGANIZATION CODE |
| | 8. PERFORMING ORGANIZATION REPORT NO. | |
| 7. AUTHOR(S) Lisa Conner, Innovative Strategies and Economics Group | 10. PROGRAM ELEMENT NO. | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Strategies and Standards Division Research Triangle Park, NC 27711 | 11. CONTRACT/GRANT NO. | |
| | 13. TYPE OF REPORT AND PERIOD COVERED | |
| 12. SPONSORING AGENCY NAME AND ADDRESS John Sietz, Director Office of Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, NC 27711 | 14. SPONSORING AGENCY CODE EPA/200/04 | |
| | 15. SUPPLEMENTARY NOTES | |
| 16. ABSTRACT This report presents a technical analysis of the economic impacts associated with the proposed NESHAP for Refractory Product Manufacturing. The analysis evaluates adjustments in the refractory products market (through price and production changes), social cost, and the resulting affects on employment, international trade, and small businesses. | | |
| 17. KEY WORDS AND DOCUMENT ANALYSIS | | |
| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
| Economic Impact Analysis (EIA) Regulatory Flexibility Analysis (RFA) | Air Pollution control economic analysis small business analysis | |
| 18. DISTRIBUTION STATEMENT Release Unlimited | 19. SECURITY CLASS (<i>Report</i>) Unclassified | 21. NO. OF PAGES |
| | 20. SECURITY CLASS (<i>Page</i>) Unclassified | 22. PRICE |